MACHINE DRAWING

BOOK 4.

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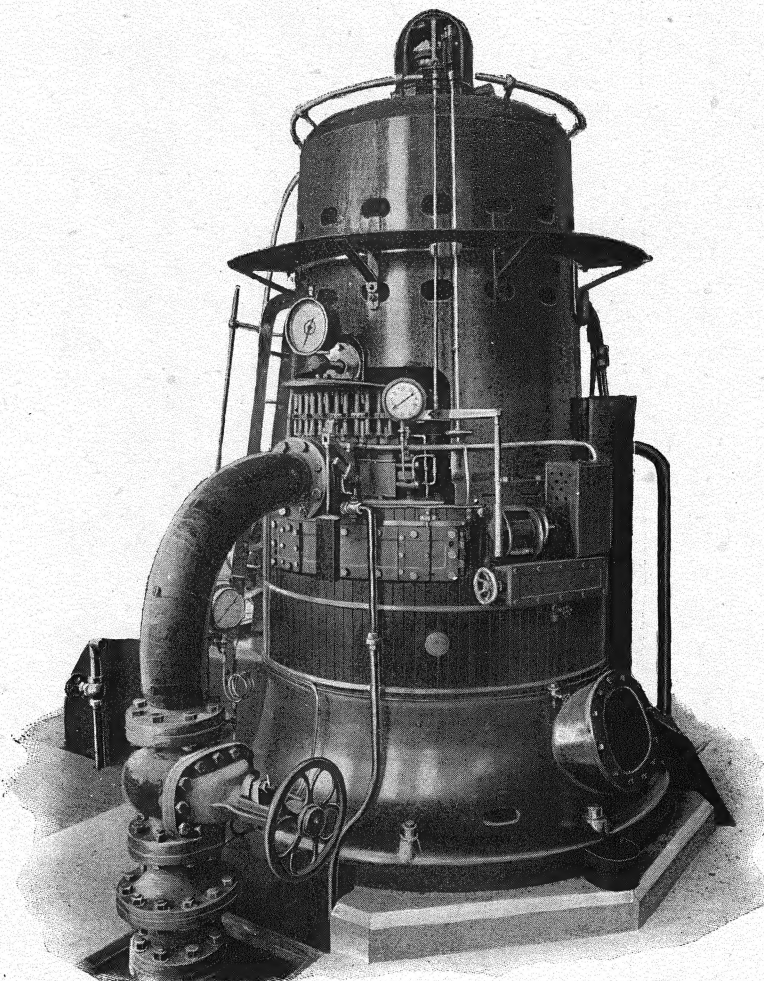

CURTIS STEAM TURBO ALTERNATOR

in the Power-House of the British Thomson-Houston Company, Limited,
Electrical Manufacturers, Rugby.

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MACHINE DRAWING,

FOR THE USE OF

ENGINEERING STUDENTS

IN

SCIENCE AND TECHNICAL SCHOOLS AND COLLEGES.

BY

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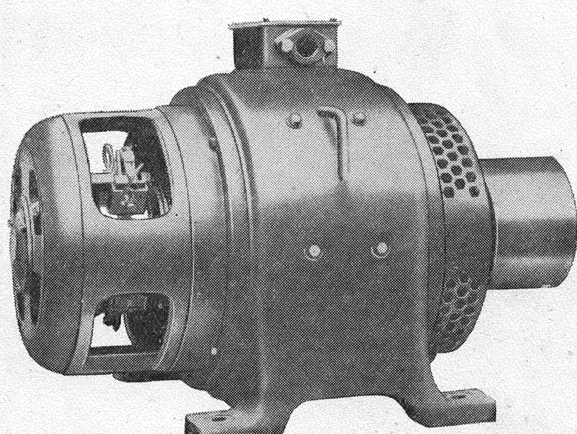

BOOK IV.

ELECTRICAL MACHINES.

JOHN HEYWOOD LTD.

(*Publishers*)

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LONDON——DUBLIN——BLACKBURN.

PREFACE TO SECTION I.

STUDENTS of Electrical Engineering should have opportunities of specialising in their Machine Drawing work and thus of becoming better acquainted with the actual design and construction of the various machines whose action and effects they study.

To meet this requirement this book is issued in the hope that it may be helpful to all students of this important branch of engineering science.

The drawings, which are made from machines as constructed by the best makers, will enable the student to verify his lecture room data on the designing of these important pieces of mechanism.

In future editions the authors purpose extending the scope of the book by the addition of sections dealing with Alternating Current Machines, Induction Motors, Rotary Converters, and other machines.

THOMAS JONES.
T. GILBERT JONES.

LIST OF PLATES.

SECTION I.

CONTINUOUS-CURRENT ELECTRIC MACHINES.

Plate I.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

GENERAL ARRANGEMENT.—The continuous-current generator, of which details are given on Plates II. to IX. inclusive, is made by the British Thomson-Houston Co. Ltd., Rugby, and is capable of generating $13\frac{1}{3}$ kilowatts at a speed of 850 revolutions per minute. The current generated has a strength of 27 amperes at 500 volts.

The magnet frame or yoke is of cast iron, and the lower half of it is cast with the bed plate and the bearings. There are four cast-steel pole pieces bolted to the inside of the ring, and the winding of the magnet bobbins is compound.

The armature is 13 inches diameter and 7 inches long over the outer space blocks, and is of the slotted drum-wound type with wave connected or series winding. The winding is made up of three coils of four turns of No. 13 B.W.G. wire

The commutator, keyed to the shaft, is $10\frac{1}{2}$ inches diameter, and has 129 copper bars rigidly clamped together. The four sets of carbon brushes are carried by the brush holder yoke which fits round the inner end of one of the bearings.

The two shaft bearings are of the self-aligning type: the shaft is supported in cast-iron swivel bushes—one bush being lined with Babbitt metal. Continuous lubrication is provided by means of oiling rings threaded on the shaft. The driving pulley is $12\frac{1}{4}$ inches diameter by $8\frac{1}{2}$ inches wide, and makes 850 revolutions per minute. The steel shaft is made much stiffer between the pulley and the armature than is the remaining portion.

EXERCISE

Complete Machine.—Draw the three views as given. If the drawing be made on a sheet of imperial size, *Scale 3″ = 1 foot;* for half imperial, use *Scale $\frac{1}{5}$ full size.*

N.B.—On no account should the above exercise be attempted until all, or at least the more difficult, details have been drawn separately.

Power required to drive the machine at full load. Current in amperes × volts = Power in watts.

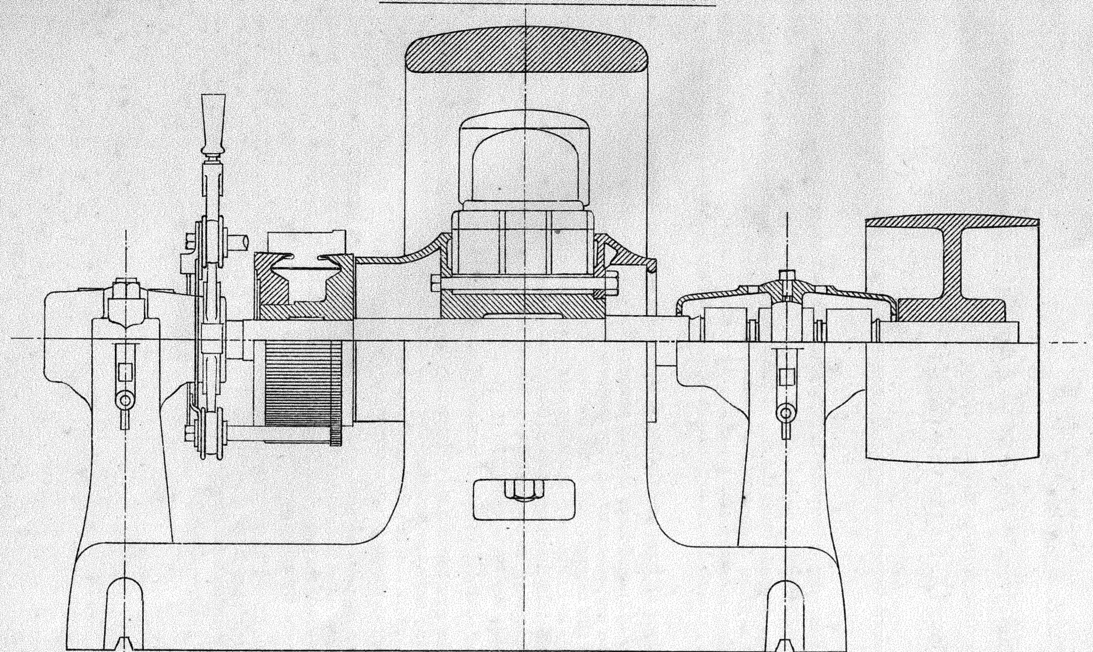
$$\frac{\text{Current in amperes} \times \text{volts}}{1000} = \text{Power in kilowatts.}$$

$\therefore$ for a machine of $13\frac{1}{2}$ kilowatts and voltage 500, current $= \dfrac{13\frac{1}{2} \times 1000}{500} = 27$ amperes.

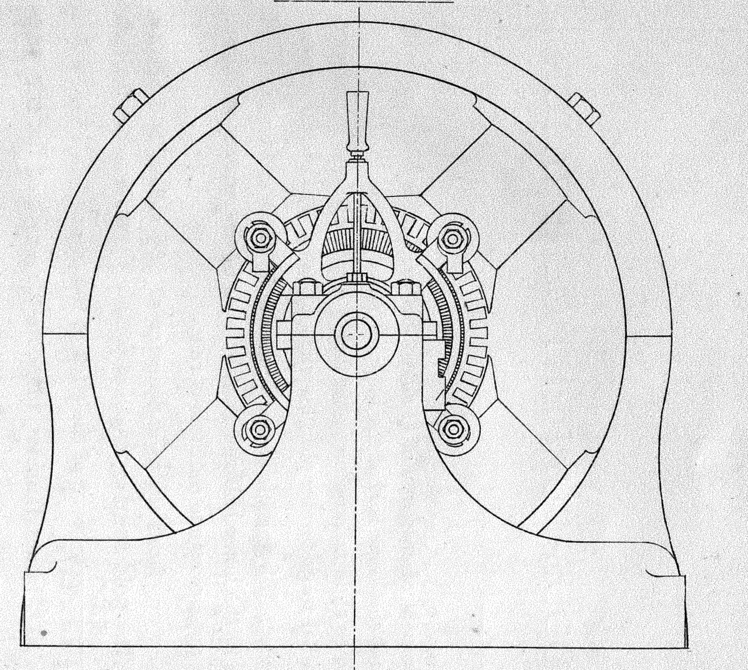
Now, 746 watts = 1 Horse-power. $\therefore$ the output of the machine is equivalent to 18·09 H.P. $\dfrac{27 \text{ amps.} \times 500 \text{ volts}}{746} = 18{\cdot}09$ H.P

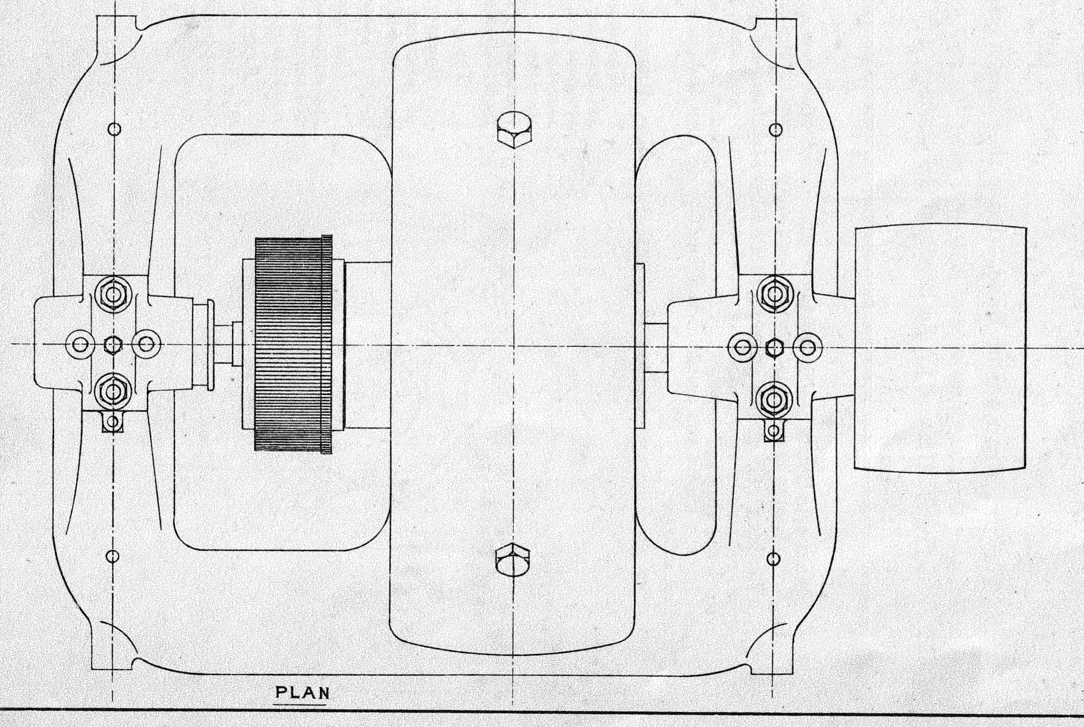
Assuming an efficiency of 90%. The power required to drive the machine $= \dfrac{18{\cdot}09 \times 100}{90} = 20{\cdot}1$ H.P.

SIDE ELEVATION AND SECTION.



END ELEVATION





PLAN

FOUR-POLE

CONTINUOUS-CURRENT GENERATOR.

GENERAL ARRANGEMENT.

Scale 1¼" = 1 Foot.

SEE PLATES II. TO IX. INCLUSIVE FOR DETAILS.

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Plate II.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

MAGNET FRAME AND BASE.—The machine base is of cast iron of U shape section, $\frac{1}{2}$ inch thick, and with it are cast the uprights for the two shaft bearings and the lower half of the magnet frame or yoke.

The base is arranged so that it may be secured to slide rails by means of four $\frac{3}{4}$ inch bolts, and is provided with four V slots to ensure its movement in a direction parallel to its former position when adjusted by the rail screws.

The upper half of the magnet yoke is secured to the lower half by means of two $\frac{7}{8}$ inch studs, which are first screwed tightly into the former, then passed down the vertical holes in the lower half and fixed by nuts in the recesses as shown. In this way, by obviating the necessity for flanges, the yoke appears as one continuous ring.

On the inside of the yoke are four curved surfaces which are faced up to a diameter of $24\frac{3}{4}$ inches, and against these the cast-steel pole pieces are fixed by $\frac{7}{8}$ inch screws. The **pole span** or length of polar arc is 8·37 inches for each pole piece on a diameter of $13\frac{5}{16}$ inches. $\therefore$ **pole span** $= \dfrac{8.37''}{\frac{1}{4} \times \pi \times 13\frac{5}{16}} =$ ·8 of the pitch of the poles.

The armature is 13 inches diameter and the pole faces $13\frac{5}{16}$ inches diameter, therefore the length of the **air gap** is $\frac{5}{32}$ inch.

EXERCISE.

Magnet Frame and Base.—Draw the three views as given. *Scale 3″ = 1 foot.* Or, draw the three views completing the end elevation and plan, and show the four pole pieces in position. *Scale $\frac{3}{16}$ full size.*

See Plates III. and IV. for details of the bearings, and Plate IX. for the pole piece.

Magnetic Circuit.—The **voltage** of the current taken from a dynamo depends upon the number of conductors or wires in series round the circumference of the armature, and the number of lines of force cut per second.

The **strength of the current** which can be taken from a dynamo depends upon the size of the armature wire, of which the carrying capacity is limited by the allowable rise of temperature; and hence, for a given diameter of armature, the stronger the current the larger must be the wires and consequently the smaller the number round the circumference, and hence the lower the voltage. Therefore, without affecting the output the armature windings may be such that there is generated a strong current of a low voltage, or a weaker current at a higher voltage.

To produce an increase of output the number of magnetic lines of force and the speed of rotation must be increased.

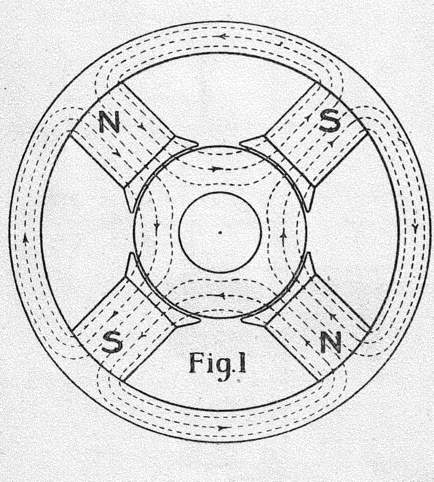


Fig. 1

The number of lines of force passing between the opposite poles may be increased by increasing the ampere-turns of the magnet winding or by increasing the cross sectional area of the magnet limbs and frame. But the advantage of the increased magnet winding is limited by the allowable magnetic density of the lines; and therefore, beyond this limiting density, the total number of lines of force must be increased by an increase in the cross sections of the poles and yoke. This latter modification makes the machine bigger.

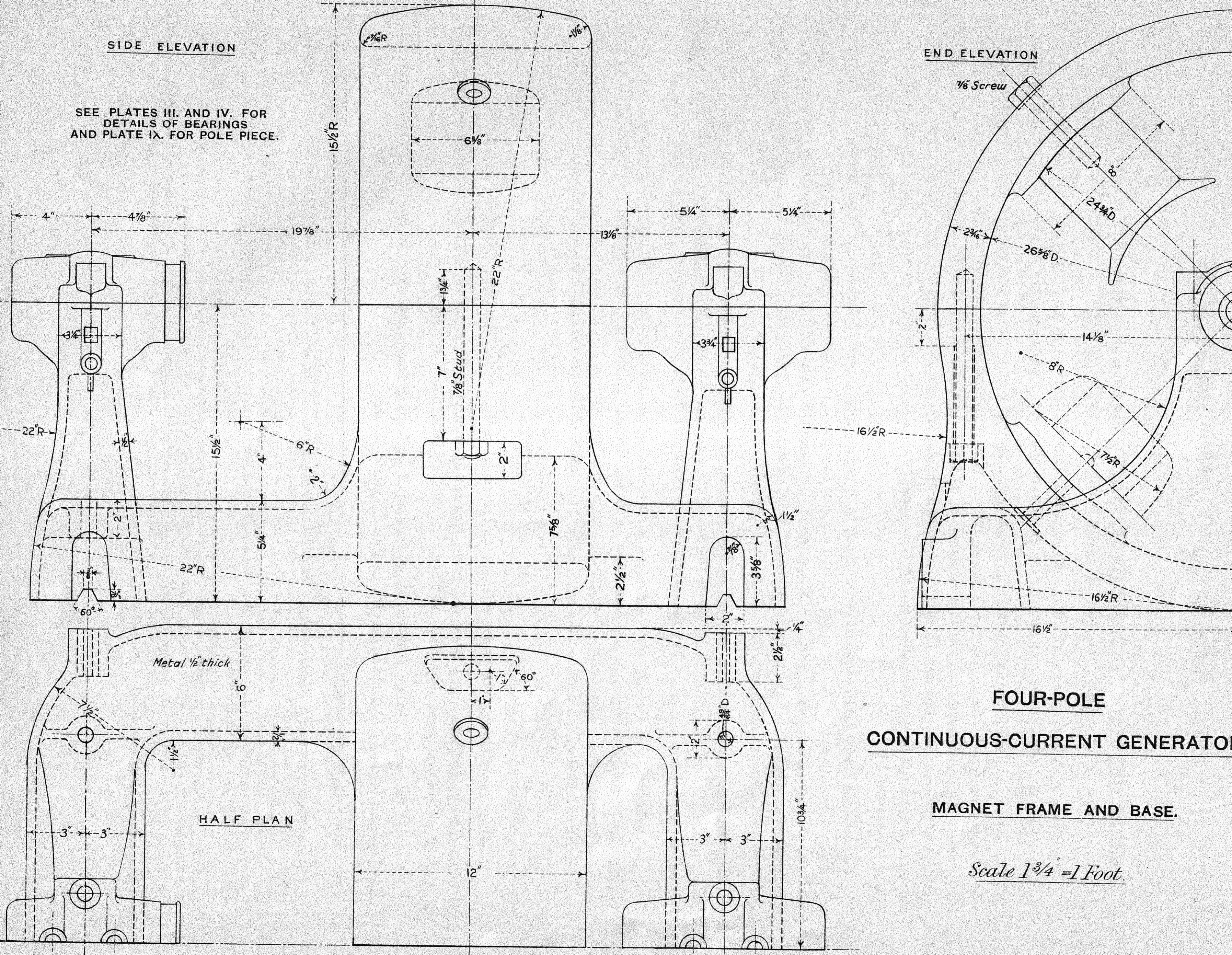
The speed of rotation is limited because of mechanical and other difficulties.

However, the number of lines of force may be increased by increasing the number of poles round the armature, so that the armature during a revolution cuts not only one set of lines, as in the bi-polar machine, but as many sets as there are pairs of poles. The magnet windings are arranged so that opposite poles are adjacent.

The number of pairs of poles used in a **multi-polar generator** depends upon the output—the greater the output the greater the number of poles—and even when the output is so small that there is little or no increase of efficiency there is generally a saving in material by using a multi-polar instead of a bi-polar machine.

Arrangement of the lines of Force for a four-pole machine, fig. 1.—The lines of force pass from a north pole through the air gap into the armature core where they divide into two branches, and return by the south poles on either side and by the yoke to the north pole from which they started.

[*Continued on Plate III.*



FOUR-POLE

CONTINUOUS-CURRENT GENERATOR.

MAGNET FRAME AND BASE.

Scale 1¾" = 1 Foot.

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Plate III.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

BEARING FOR COMMUTATOR END OF SHAFT.—The given views represent completely the construction of the bearing for the support of the commutator end of the shaft.

In the case of all high-speed shafts it is very important that the bearing be long compared with the diameter of the shaft, and then, to ensure accurate alignment, the bushes are allowed a slight swivel motion about their central points.

The upright and the lower half of the bearing are cast with the machine base and magnet yoke; and the cap is held down by two $\frac{3}{4}$ inch studs. On the inside of the cap is a ridge, and across the lower half of the bearing, a bridge piece, which are bored out spherically to a diameter of $3\frac{1}{2}$ inches to form a swivel support for the bush. There is considerable space round the outside of the bush, and the lower part of it forms the reservoir for the oil which is conveyed to the shaft by means of oiling rings. The quantity of oil in the bearing is shown by the oil gauge cast on the side of the upright.

The cast-iron bush, for the support of the shaft, is $6\frac{1}{2}$ inches long, bored $1\frac{1}{2}$ inches diameter, and is not provided with a white metal lining. On the upper surface are cast two grooves so that the oiling rings may be threaded over the bush and allowed to hang on the shaft. When the shaft rotates the rings rotate, and since they hang in the oil below a continuous supply of lubricant is conveyed to the shaft on the surface of the rings. The oil from the shaft collects in the three semi-circular grooves and drains into the oil supply.

The bush is prevented from turning in the direction of rotation of the shaft by the end of the screw in the cap fitting in the $\frac{7}{16}$ inch slot which is cut across the top of the spherical portion. Oil is supplied to the bearing through the two $\frac{3}{4}$ inch holes in the cap. The brush-holder yoke fits round the end of the bearing in the $\frac{3}{4}$ inch circular groove.

The construction of the oil gauge is evident from the large detailed drawing. The horizontal branch leading from the bottom of the reservoir is in communication with the vertical glass tube which is held in position by a $\frac{5}{8}$ inch diameter screwed plug. The lower end of the tube rests on a lead washer, and between the plug and the top of the tube is a washer of maple with a notch on the edge, so that the inside of the tube is at atmospheric pressure.

EXERCISES.

1.—**Cast-Iron Bush.** Draw the side, end and sectional elevations and the plan. *Scale full size.*

2.—**Complete Bearing.** Draw the given views; but, instead of the complete sectional elevation as given, make the left-hand half in outside elevation, and the right-hand half in section. *Scale $\frac{2}{3}$ full size.*

3.—**Oil Gauge.** Distinct from the above drawing of the bearing draw completely the front, side and sectional side elevations and plan of the gauge as detailed in Fig. 5. *Scale full size.*

Comparison between a Bi-polar and a Multi-polar Machine.—If, say, in a four-pole machine the armature winding is such that the conductors are divided into two sets connected in parallel with four lines of brushes, the voltage produced in each set will be the same as with a bi-polar machine with equal pole strengths and the same speed, since half as many conductors cut twice as many lines of force per revolution. And as there are four sets of conductors connected in parallel the main current will be four times the strength of that flowing through each set. With a bi-polar machine the main current will be twice as great as that flowing through each conductor, since they are divided into two sets in parallel.

Now in the two machines the armature conductors are of the same cross section and number, and therefore the maximum currents through the conductors of the two armatures are equal: hence, it follows, that in the case of a four-pole machine with **parallel armature winding** the main current will have the same voltage as that from the two-pole, but will be double the strength.

Again, if the conductors on the four-pole armature be **wave or series wound**, *i.e.*, arranged to form two sets in parallel, the main current strength will be the same as for the two-pole machine, but as the same number of conductors—$\frac{1}{2}$ total number—cut twice as many lines of force per revolution, the voltage of the current will be twice as great.

[*Continued on Plate IV.*

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

BEARING FOR COMMUTATOR END OF SHAFT.

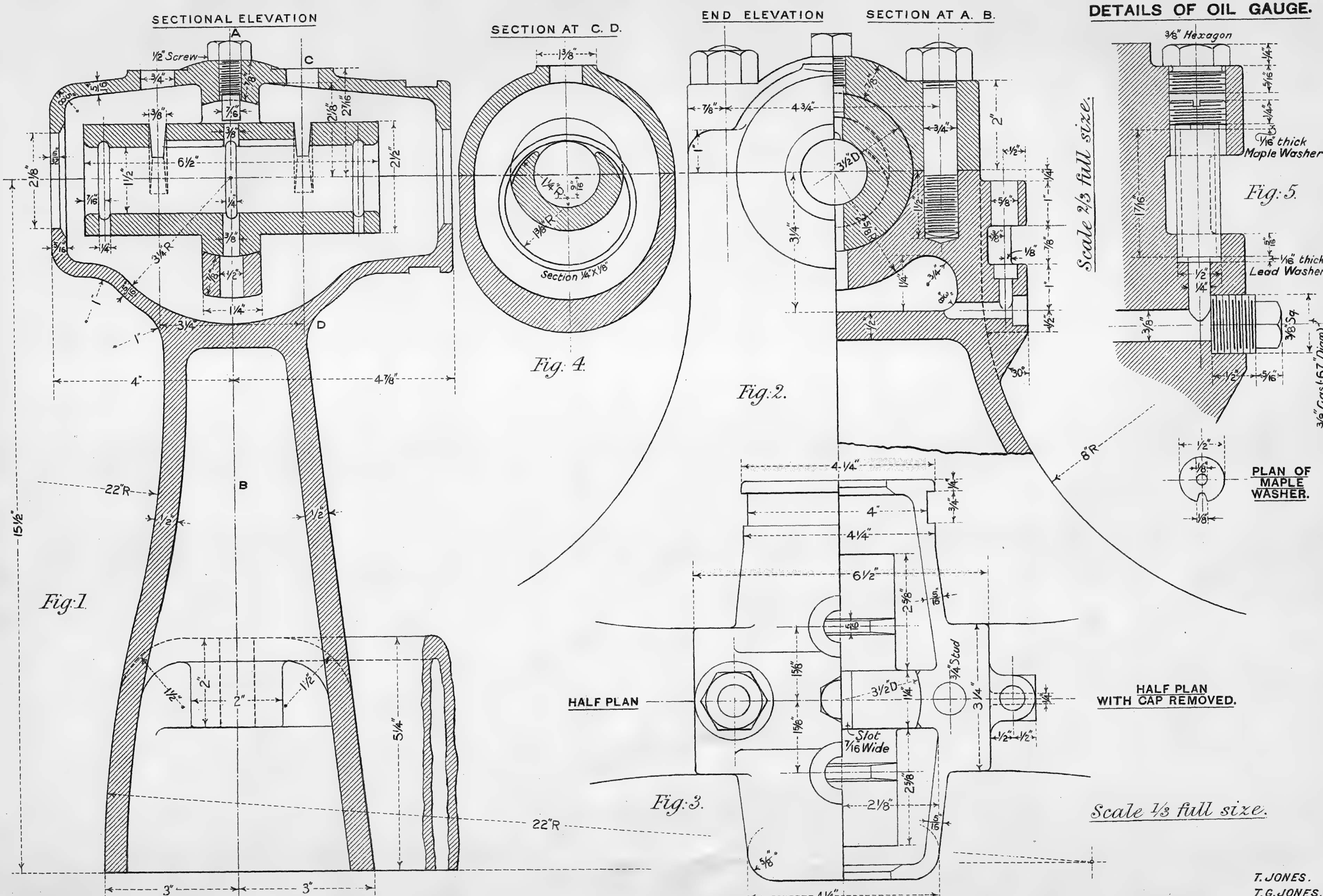

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

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Plate IV.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

BEARING FOR PULLEY END OF SHAFT.—The two shaft bearings are of the same design, but in this case the bearing is for a larger diameter of shaft. The shaft projects beyond the bearing and is fitted with the driving pulley. As will be seen on reference to the text for Plate I., the power required to drive the machine at full load is about 20 H.P. The absorption of this power in the rotation of the armature conductors across the magnetic lines of force produces a twisting moment only on the portion of the shaft between the pulley and the armature; and this, together with the greater bending moment on this portion of the shaft, due to the pull of the driving belt, make it imperative that the bearing and shaft at the pulley end be much stiffer than at the other end of the machine.

The cast-iron bush is bored $2\frac{1}{8}$ inches diameter and has a length of $8\frac{1}{2}$ inches, four times the diameter. The lining of Babbitt metal is $\frac{3}{16}$ inch thick and is held securely in position by the enlarged ends and the four longitudinal ribs. The position of the oiling rings on the shaft is shown in Fig. 4, and the oil gauge, which is similar to that on the other bearing, is detailed in Fig. 2.

For a more detailed description of the bearing see the text to Plate III.

EXERCISE.

Bearing.—Draw the four given views, but make the left-hand half of Fig. 1 an outside view instead of a section. *Scale $\frac{3}{4}$ full size.*

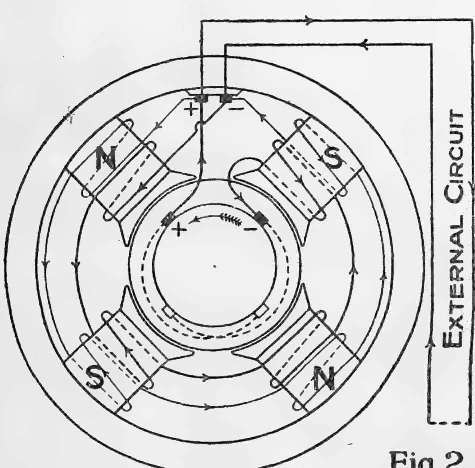

Fig. 2

Magnet Winding.—In the example of which details are given the magnets are **compound wound,** *i.e.*, round each pole are two distinct coils conveying currents, viz.—a series coil and a shunt coil. The series coil forms part of the main external circuit and so conveys the full strength of current; and the shunt coil forms a shunt of the main circuit, so that only a small current passes through it. The object of a compound winding is to enable a constant voltage to be maintained under widely differing loads. In most modern generators it is usual to give the series coil sufficient turns so that when the current is a maximum the voltage is slightly above the normal. The strengthening of the magnetic field at full load prevents sparking at the brushes.

Fig. 2 indicates diagrammatically the windings and direction of current for a four-pole machine with the north and south poles situated as in Fig. 1.

The dimensions of the cross sections of the yoke, the pole pieces and the armature core, are determined by the total number of lines of force required and the magnetic densities for the materials, *i.e.*, the maximum allowable number of lines of force per square inch of section.

The amount of magnet winding, or the number of ampere turns per pole, is determined by the magnetic densities and the length of the magnetic circuit.

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

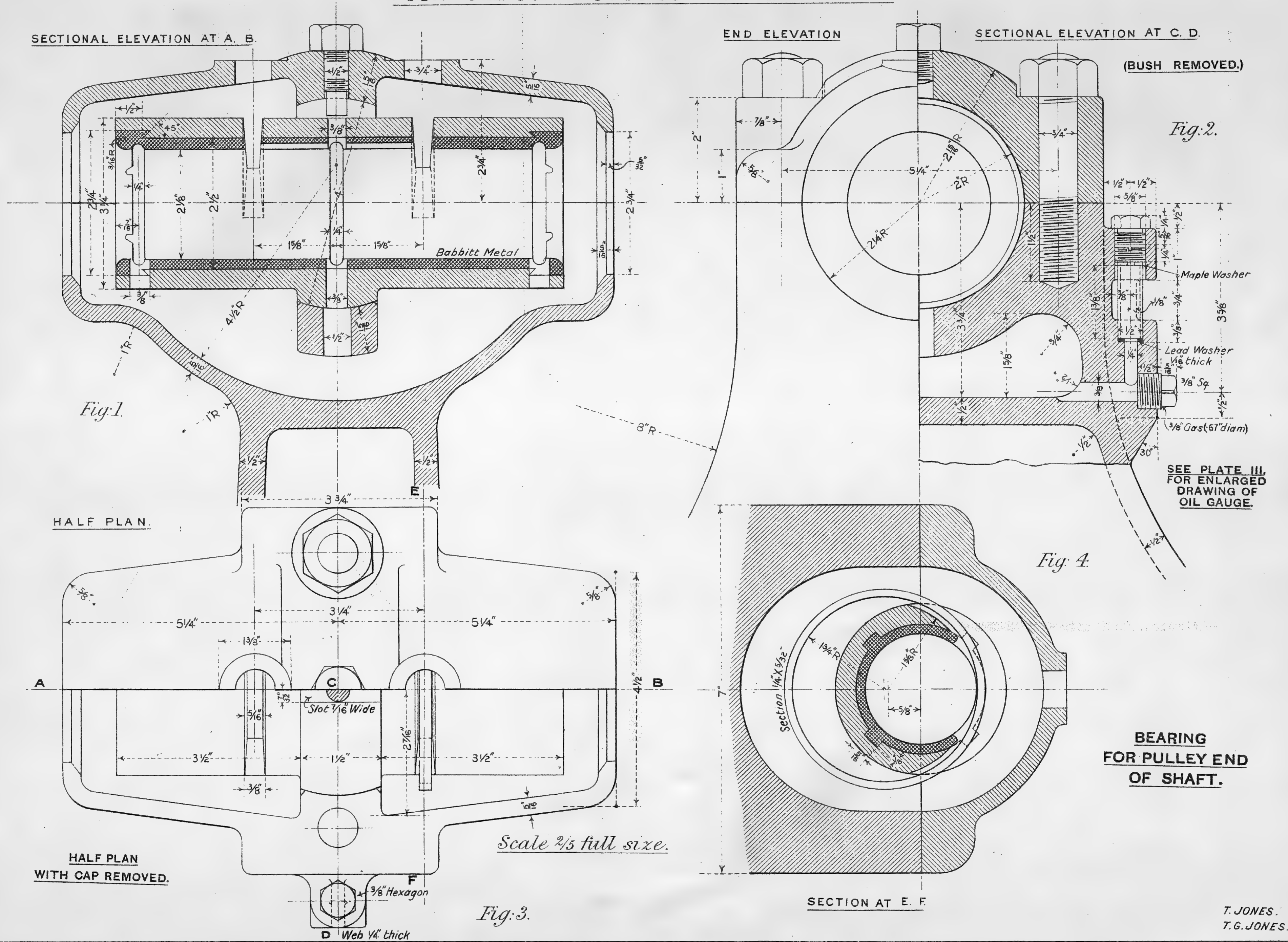

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Plate V.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

ARMATURE.—The armature is of the slotted drum-wound type, and consists of a large cast-iron spider and end plate, the slotted armature punchings and space blocks and the armature conductors, the last-named of which not being shown on the drawings.

The cast-iron spider is keyed to the steel shaft by a $\frac{5}{8}$ inch square steel key, and has upon its outer surface four longitudinal ribs over which pass the slotted armature iron punchings. With the spider is cast one end plate for the clamping together of the core discs, and the other plate fits on the end of the spider and is held by four $\frac{5}{8}$ inch steel bolts. Along the surface of the spider is a $\frac{3}{8}$ inch steel key which serves to drive the core discs: the key is passed from the commutator end through the $\frac{5}{8}$ inch cored hole in the flange.

The iron punchings are each 13 inches diameter with $6\frac{1}{2}$ inches hole and $\frac{3}{8}$ inch keyway, and provided with 43 slots, 1·065 inch × ·417 inch. The sheets are insulated from one another by insulating varnish or sheets of paper, and are ·025 inch thick, except the eight pairs which are against the space blocks, and these have a thickness of ·035 inch. Care should be taken that the laminations are accurately stamped in order to avoid the necessity for filing or milling, as either operation increases the core losses.

The space blocks are $\frac{1}{4}$ inch thick, and made in segments comprising eight slots, and these are riveted to the adjacent thicker punchings, five of them forming a complete ventilating duct. The armature core is divided into three portions, each 2 inches thick, by the four sets of space blocks. To facilitate the dissipation of the heat generated by the passage of the current through the armature conductors and that due to hysteresis of the core and the eddy currents, the spider is designed so that a fan effect is produced, the air being forced through the space blocks between the laminations.

For the support of the end connections of the conductors in the slots the two flanges clamping the laminations are provided with curved sleeves.

The winding is a **two-circuit wave** or **series winding** and consists of sets of three coils of four turns of No. 13 B.W.G. wire, making 24 wires per slot. The armature resistance is quarter the resistance of the whole length of wire since the two halves are in parallel, and amounts to ·477 ohm at 25° C. Further particulars of the winding are given below.

The peripheral velocity of the armature is $\left(\frac{13 \times \pi \times 850}{12} =\right)$ 2894 feet per minute.

EXERCISES.

1.—**Armature Punching.** Draw the complete disc showing the 43 slots. *Scale $\frac{3}{4}$ full size.*
2.—**Space Block.** Draw three views of each of the space blocks A and B. *Scale full size.*
3.—**Armature Punching and Space Blocks.** Draw an elevation and a plan of a punching with the five space blocks riveted in position. *Scale $\frac{3}{4}$ full size.*
4.—**Flange.** Draw the sectional and end elevations and plan. *Scale $\frac{3}{4}$ full size.*
5.—**Spider.** Draw the longitudinal sectional elevation, the end elevation and the plan. *Scale $\frac{3}{4}$ full size.*
6.—**Complete Armature.** Draw the two given views and add a plan. *Scale $\frac{1}{2}$ full size.*

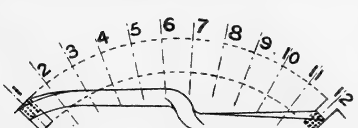

Fig. 3

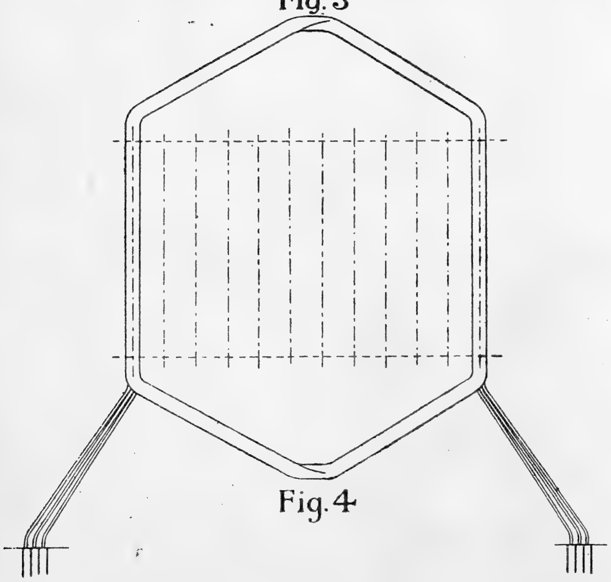

Fig. 4

Armature Winding.—Figs. 3 and 4 show one complete winding for the armature. Fig. 3 is an elevation, and Fig. 4, a plan with the armature and commutator surfaces developed.

There are three coils, **a**, **b**, **c**, each of four turns, passing from the upper half of **slot 1** to the lower half of **slot 12**. Another winding would pass from the upper half of slot 12 to the lower half of slot 23, and so on.

In this way 43 windings, such as that indicated, would be required to go round the complete circumference. One end of the **coil a** is connected with **commutator bar** 1 and the other end to **bar 65**. The two ends of **coil b** are connected with the commutator **bars 2** and **66** respectively, and so on.

[*Continued on Plate VI.*

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

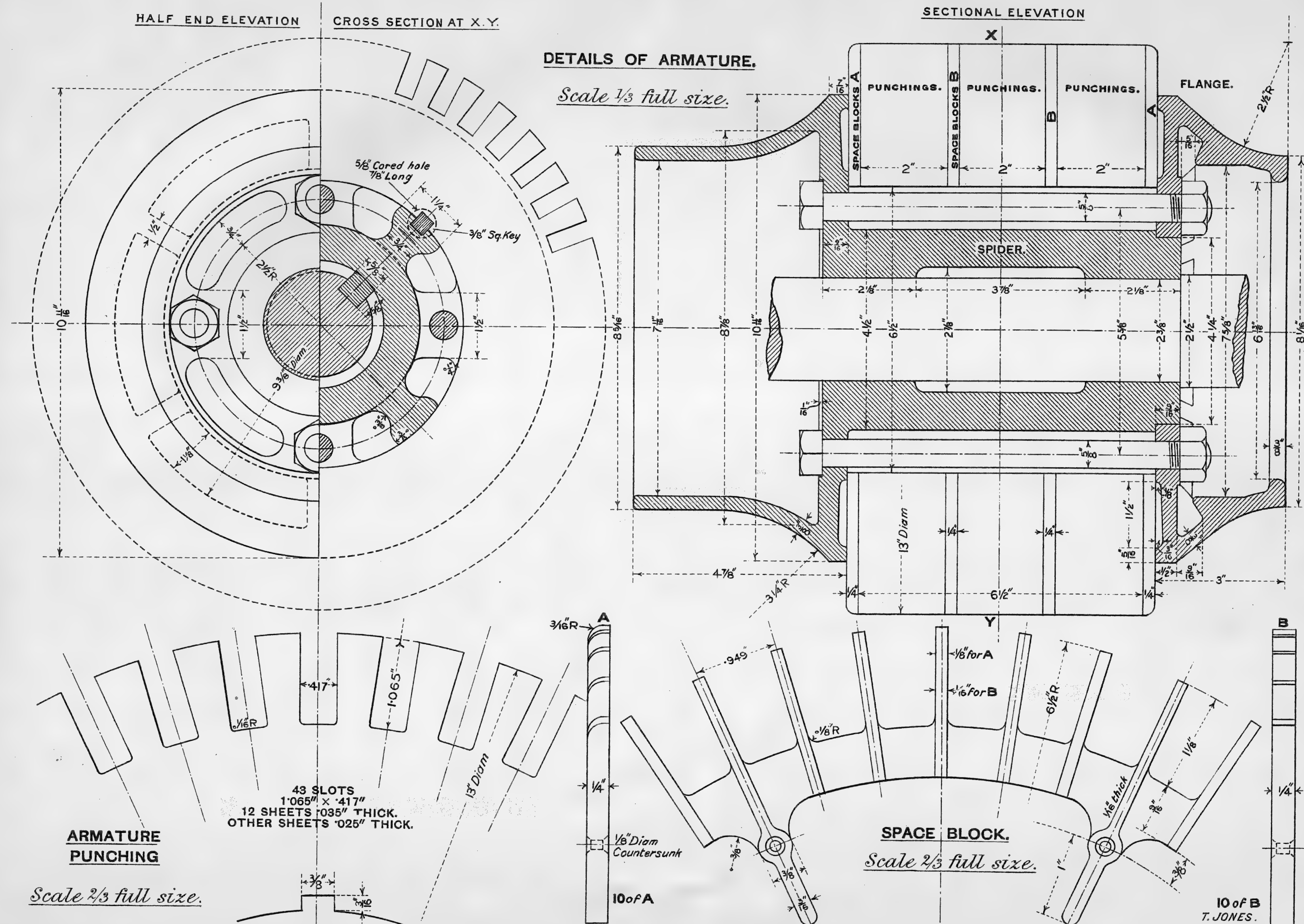

Plate VI.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

COMMUTATOR.—The commutator is $10\frac{1}{2}$ inches diameter and has 129 copper bars, with a rubbing length of $3\frac{1}{4}$ inches. The cast-iron sleeve is securely fixed to the shaft by a steel key, $\frac{1}{2}$ inch square, and the stout malleable iron cap or clamping ring, which fits over the end of the sleeve, is held by six $\frac{9}{16}$ inch stud bolts. Details of the clamping edges on the sleeve and cap are given in Fig. 3, and the commutator bar is detailed in Fig. 4. It will be seen that the outer surfaces are slightly coned so as to provide a rigid bearing surface for the bars.

The bars are insulated from one another by sheets of mica, ·03 inch thick, placed between them; and the insulating end rings are moulded to shape before being placed in position. A sleeve of mica is also placed against the inside edges of the bars.

To facilitate the removal of the cap at any time there are two $\frac{1}{2}$ inch tapped holes on the face for the insertion of bolts by means of which the pull may be exerted. At the end near the armature the bars are turned to a diameter of $10\frac{5}{8}$ inches for a length of $\frac{1}{2}$ inch, and in the end of each bar is a curved slot, ·08 inch wide, into which two ends of the armature coils are soldered.

The peripheral speed of the commutator is $\left(\frac{10\frac{1}{2} \times \pi \times 850}{12} = \right)$ $2337\frac{1}{2}$ feet per minute.

EXERCISES.

1.—**Commutator Bar.** Draw the views in Fig. 3, and add a plan. *Scale full size.*

2.—**Commutator Sleeve.** Draw a sectional and an end elevation and also a plan. *Scale full size.*

3.—**Clamping End Plate.** Draw three views as in No. 2. *Scale full size.*

4.—**Complete Armature.** Draw the two given views and add a plan projected from the end elevation. *Scale $\frac{3}{4}$ full size.*

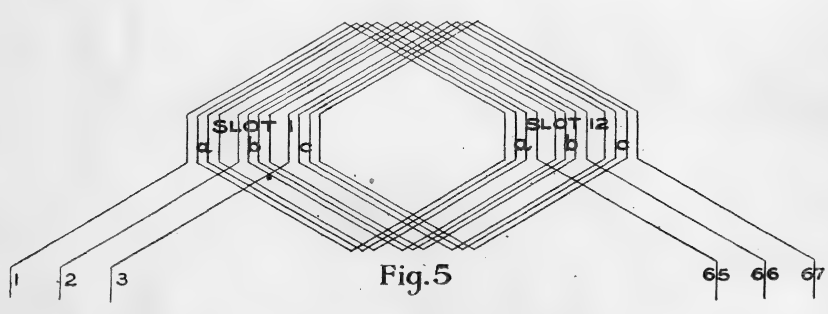

Fig. 5

ARMATURE WINDING—*Continued.*

Fig. 5 is a diagrammatical representation of the winding.

The complete triple coil winding of the armature is too complicated to represent diagrammatically on a small scale, but it will be well to study the corresponding case for a single coil winding with $\frac{1}{3}$ the number of commutator bars, viz.: $\left[\frac{129}{3} = \right]$ 43 (see Fig. 6).

[*Continued on Plate VII.*

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

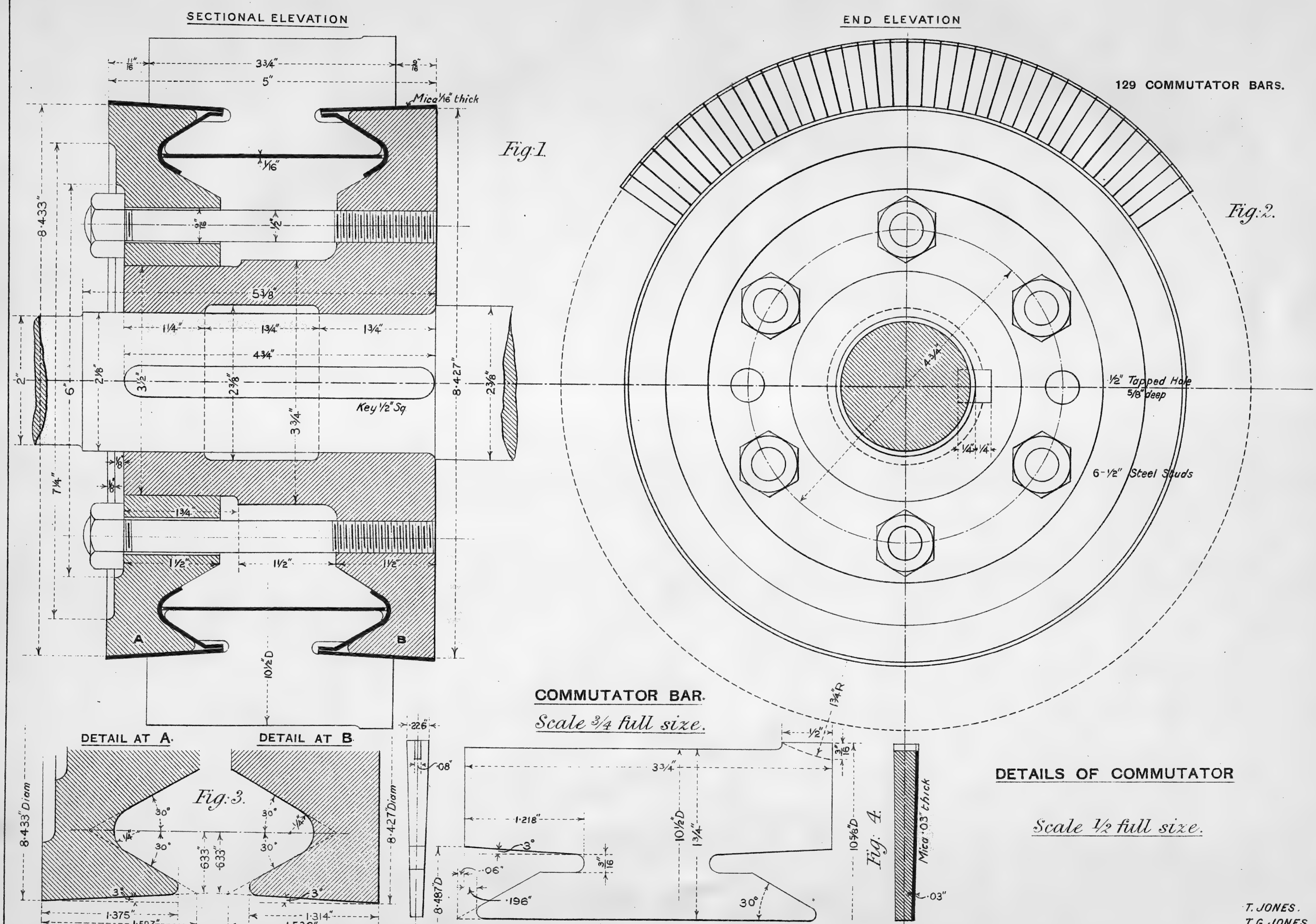

Plate VII.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

SHAFT.—The dynamo shaft is of steel, and has a total length of $47\frac{3}{4}$ inches : the positions of the armature, commutator, driving pulley and bearing bushes on the shaft are indicated on the drawing. As previously explained in connection with the shaft bearing Plate IV. the shaft between the driving pulley and the armature is stiffer than the other portion. The journals for the pulley and commutator ends of the shaft are $2\frac{1}{8}$ inches and $1\frac{1}{2}$ inches diameter respectively; and at A and B just beyond the bushes oil throwers are formed on the shaft so that the oil may not travel beyond the bearings.

All the keys are made of cold rolled steel of square section, and those for the commutator and the armature are fitted into the shaft. As shown in the enlarged section the key ways in the shaft have a depth equal to one half the thickness of the key.

Assuming that the power required to drive the machine be 20 H.P., and the speed 850 revolutions per minute; then, the twisting moment "T" is given by :—H.P. $= \frac{2\pi N T}{33{,}000 \times 12}$ or $T = \frac{\text{H.P.} \times 33{,}000 \times 12}{2\pi N}$ where T = Twisting moment in inch lbs., N = revos. per minute, $\therefore T = \frac{20 \times 33{,}000 \times 12 \times 7}{2 \times 22 \times 850} = 1482$ inch lbs.

Driving Pulley.—The pulley is $12\frac{1}{4}$ inches diameter by $8\frac{1}{2}$ inches wide, and is secured to the 2 inch diameter shaft by a $\frac{1}{2}$ inch square steel key. It is placed as near as possible to the bearing to reduce the bending strain on the shaft due to the pull of the belt.

The velocity of the belt $= \frac{12\frac{1}{4} \times \pi \times 850}{12} = 2{,}727$ ft. per min.

The belt transmitting 20 H.P. will produce an effective tension t, given by :—

$$\text{H.P.} = \frac{t \times \text{vel. of belt in ft. per min.}}{33{,}000} \qquad \therefore t = \frac{20 \times 33{,}000}{2{,}727} = 242 \text{ lbs.}$$

EXERCISES.

1.—**Shaft.** Draw the given view, *Scale $\frac{1}{2}$ full size*, and add cross sections through the commutator and armature keys, *Scale full size.*

2.—**Driving Pulley.** Draw the two given views and add a plan. *Scale $\frac{3}{4}$ full size.*

3.—**Shaft with Fittings.** Draw an elevation of the shaft, and show in section, in the correct positions on the shaft, the commutator, armature and driving pulley. *Scale $\frac{1}{2}$ full size.*

In order to make the drawing on a half imperial sheet break the shaft at the bearings and bring the ends closer together.

ARMATURE WINDING—*Continued.*

The short radial lines represent the wires in the slots; the outside lines, the end connections at the back of the armature; and the front connections with the commutator bars are represented by the inside lines.

On investigating the direction of flow of the current through the conductors it will be found that there are only two paths through the winding from a negative to a positive brush, and hence only two lines of brushes are absolutely necessary; but in many cases, as in the generator detailed in the Plates, in order to lessen the length of the commutator there are as many sets of brushes as there are poles.

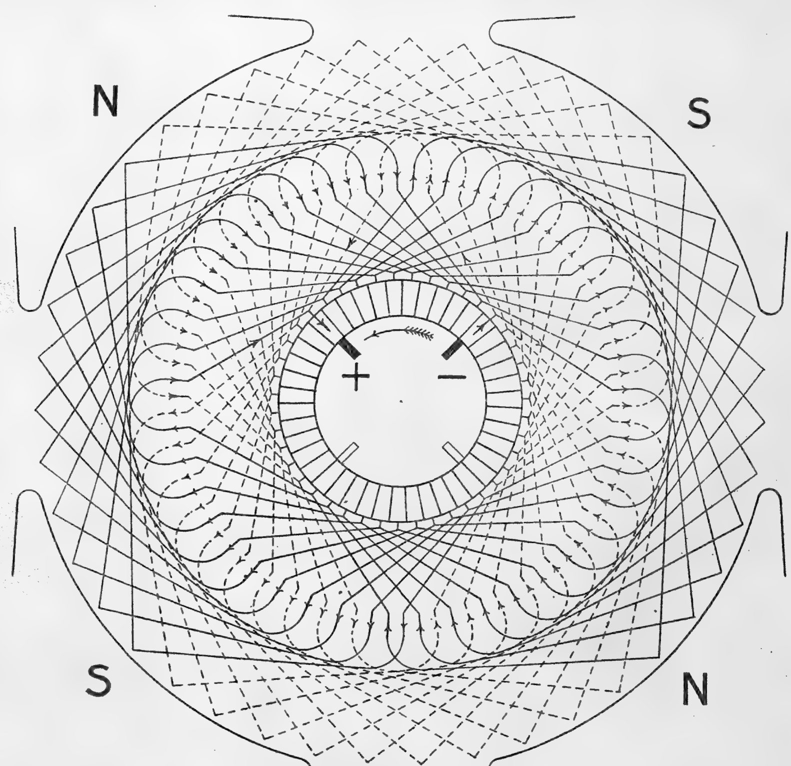

Fig. 6

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

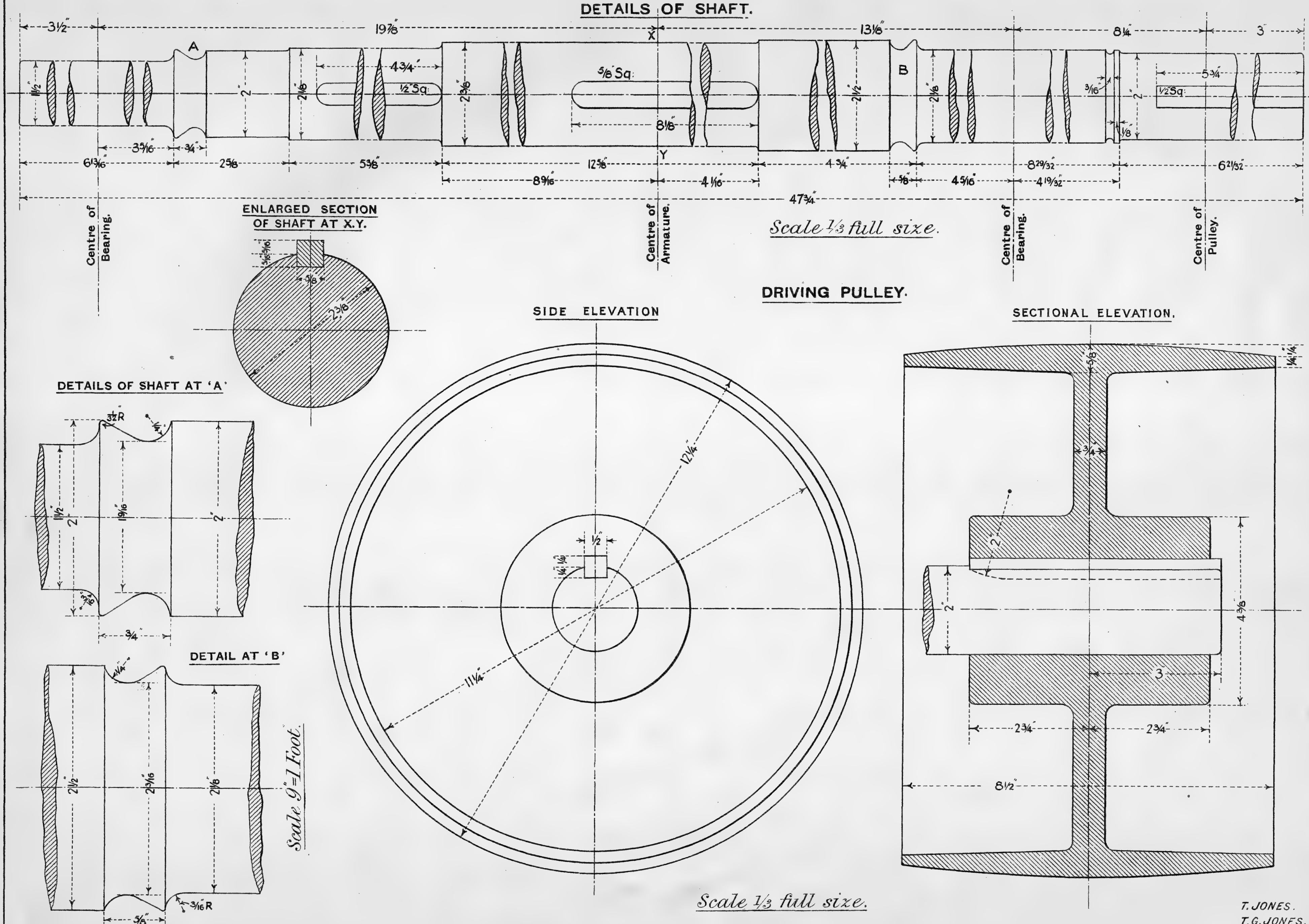

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Plate VIII.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

BRUSH-HOLDER YOKE.—The yoke which carries the four sets of brushes is of cast iron and made in halves, the two halves being fastened together by two $\frac{7}{16}$ inch studs. The yoke fits over the end of the shaft bearing at the commutator end, and is capable of an angular displacement for the adjustment of the brushes. Each half of the yoke has two arms—at 45° on either side of the vertical—at the ends of which are fixed the brass brush-holder studs. The upper half carries the binding spindle so that the yoke may be clamped when the brushes are adjusted in a non-sparking position. Each stud is insulated from the arm which carries it by a bush of *fibre*, and two large washers of the same material which fit on the ends of the bush.

Two carbon brushes—detailed on Plate IX.—are carried by each stud, and since the diametrically opposite pairs of brushes are of the same polarity they are connected by semi-circular copper strips, section $\frac{1}{2}$ inch × $\frac{1}{8}$ inch, which are wound with insulating tape to within $1\frac{1}{4}$ inches of each end. A copper connection is riveted to each end of the semi-circular ring and passed under the nut and washer on the end of a brush-holder stud. The two connecting rings are placed in different planes by the end connections of one of them being bent forward. The positive and negative terminals of the machine are at the ends of the two upper arms.

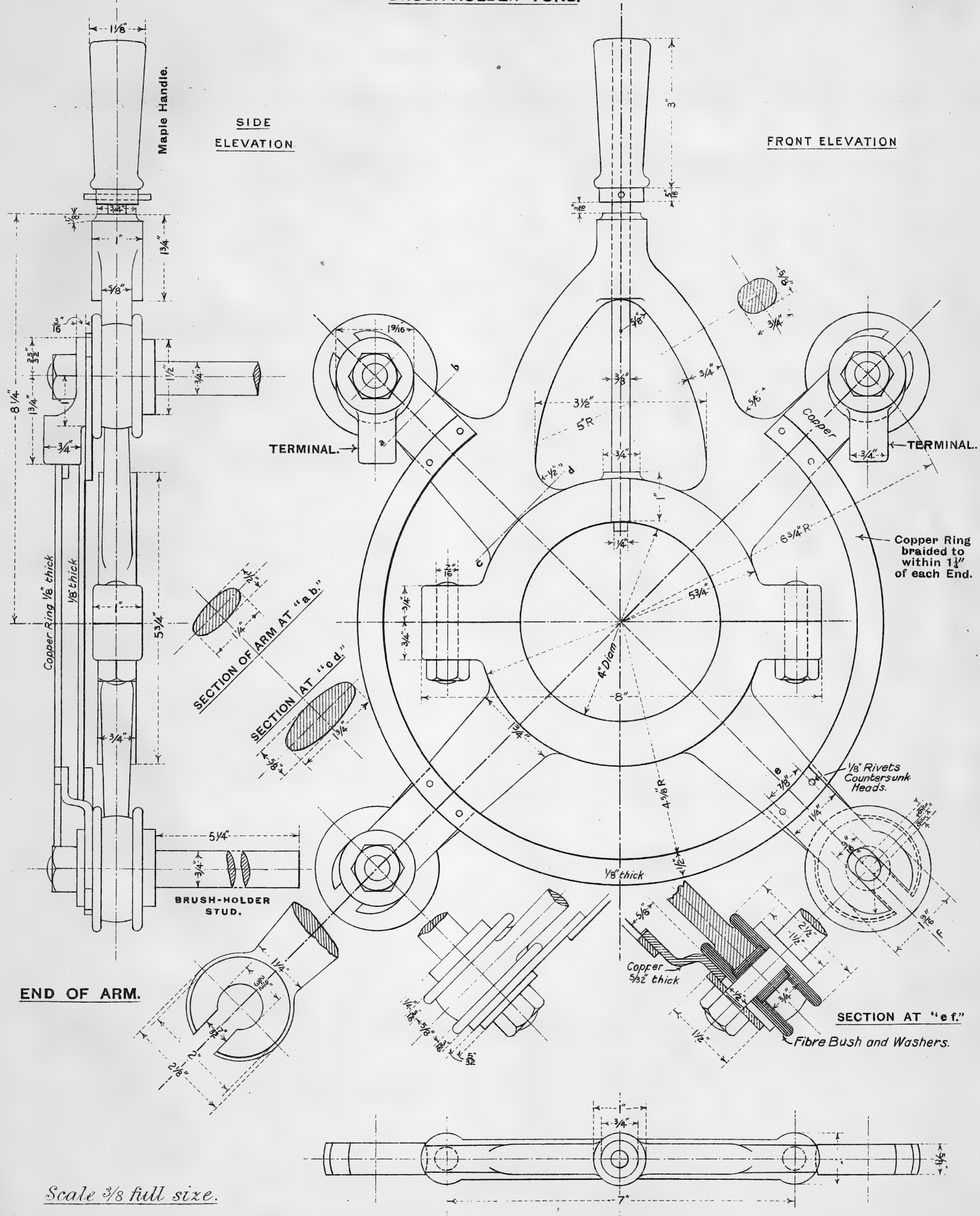
EXERCISES.

1.—**Brush-holder Yoke**. Draw the front and side elevations and the plan of the two halves of the yoke, not showing the studs or other fittings. *Scale $\frac{3}{4}$ full size.*

2.—**Brush-holder Yoke with Fittings**. Draw the front and side elevations and complete plan, and also the additional views of the ends of the arms. *Scale $\frac{1}{2}$ full size.*

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

BRUSH-HOLDER YOKE.



Scale 3/8 full size.

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Plate IX.—FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

CARBON BRUSH HOLDER.—The drawing represents one of the eight carbon brushes which are used on the four-pole generator. The body of the holder is of brass, and clamped on the $\frac{3}{4}$ inch diameter stud by a $\frac{1}{4}$ inch screw. The brush box, or the end through which the rectangular carbon block passes, is made of sheet brass, bent to shape, and bolted to the main piece.

The bottom end of the carbon is bevelled to an angle of about 17°, and the vertical edges are bevelled because of the rounded corners of the brush box. A tinned copper cap, to the under side of which the flexible pigtail is securely fastened, is sweated on to the top of the carbon. The other end of the flexible connection is fastened to the brush-holder body by a $\frac{1}{4}$ inch screw.

The pressure of the brush against the commutator—usually about $1\frac{1}{2}$lb. per sq. inch—is produced by a coiled spring. The coil is placed in the gap at the back of the holder; one end of the spring goes through the slot in the $\frac{1}{4}$ inch bolt which passes across the gap, and the other end rests on the top of the brush. By turning the spring lever attached to the bolt head in an anti-clockwise direction the coil is unwound; and this unwinding causes the free end of the spring to press on the brush. The pressure is regulated by the amount of turning of the spring lever, and when it is sufficient the lever is held in one of the four notches projecting from the top edge of the gap.

To prevent sparking the brushes should be in contact with those commutator bars which are connected with the armature conductors in the neutral zones of the magnetic field, *i.e.*, the spaces between the poles across which pass only very few lines of force. For a drum winding, when the armature is stationary, the conductors in the neutral zones are connected with the commutator bars on the centre-lines through the poles; and hence, the theoretical positions of the brushes would be on these centre-lines. However, during the rotation of the armature the magnetic field is distorted, and it becomes necessary to move forward the brushes through a small angle, called the *angle of brush lead*, from their theoretical positions.

Pole Piece, fig. 4.—The pole pieces are of cast steel and of circular section with enlarged pole faces. The outer ends are turned to a diameter of $23\frac{3}{4}$ inches to fit against the bored facings in the magnet yoke; and the pole faces are bored to a diameter of $13\frac{5}{16}$ inches, so leaving an air space of $\frac{5}{32}$ inch round the armature. The edges of the pole face are rounded and curved to a radius of 15 inches in order to lessen the sudden change of magnetic density in the teeth of the armature core when approaching or leaving a pole face.

The pole face is of much greater area than the cross section of the pole so that the magnetic density across the air gap may be considerably less than that through the pole.

The cast steel used for pole pieces is very similar in magnetic properties to wrought iron and must not be confused with the cast steel used for tools.

EXERCISES.

1.—**Brush Holder.** Draw the two given views and add two end elevations. *Scale full size.*

2.—**Brushes on Commutator.** Draw an end elevation of the commutator, showing the four sets of brushes in their correct positions relative to the poles, assuming an angle of brush lead of 5°. *Scale $\frac{3}{4}$ full size.*

3.—**Pole Piece.** Draw the two given views and add a plan. *Scale $\frac{3}{4}$ full size.*

FOUR-POLE CONTINUOUS-CURRENT GENERATOR.

CARBON BRUSH HOLDER.

Scale full size.

SIDE ELEVATION.

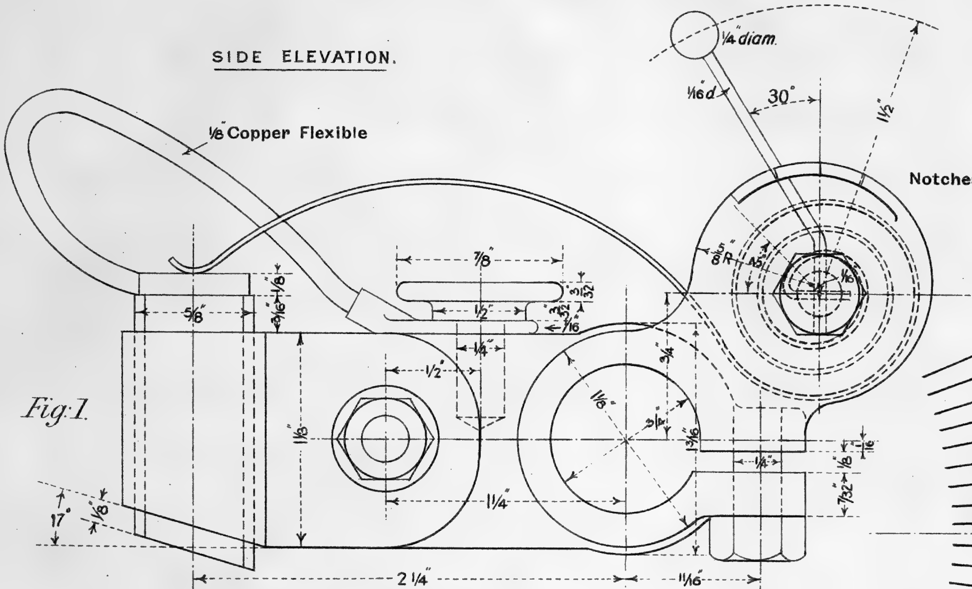

Fig: 1.

PLAN

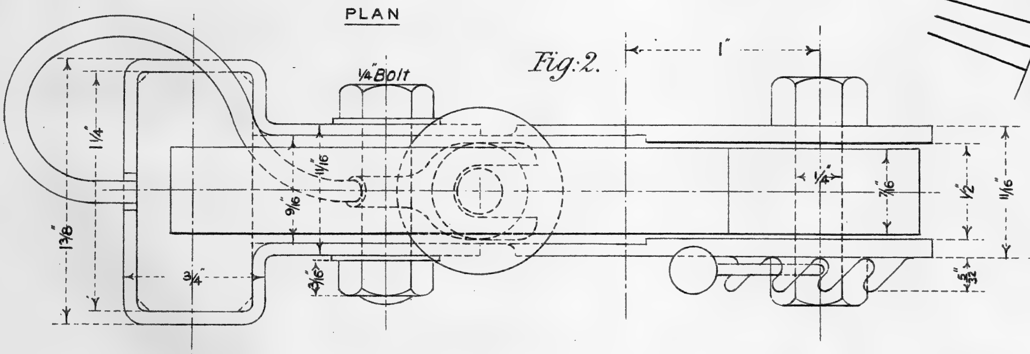

Fig: 2.

POSITION OF BRUSH WHEN ON COMMUTATOR.

Scale 1/2 full size.

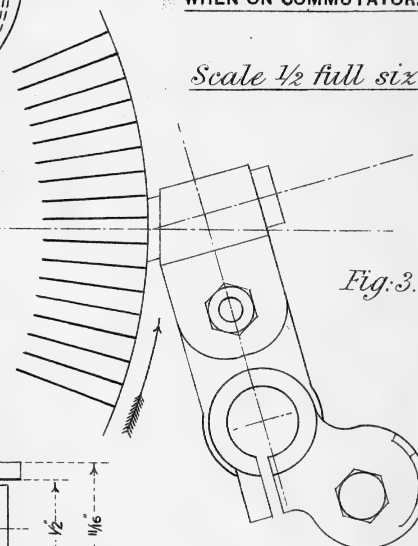

Fig: 3.

POLE PIECE.

SIDE ELEVATION END ELEVATION

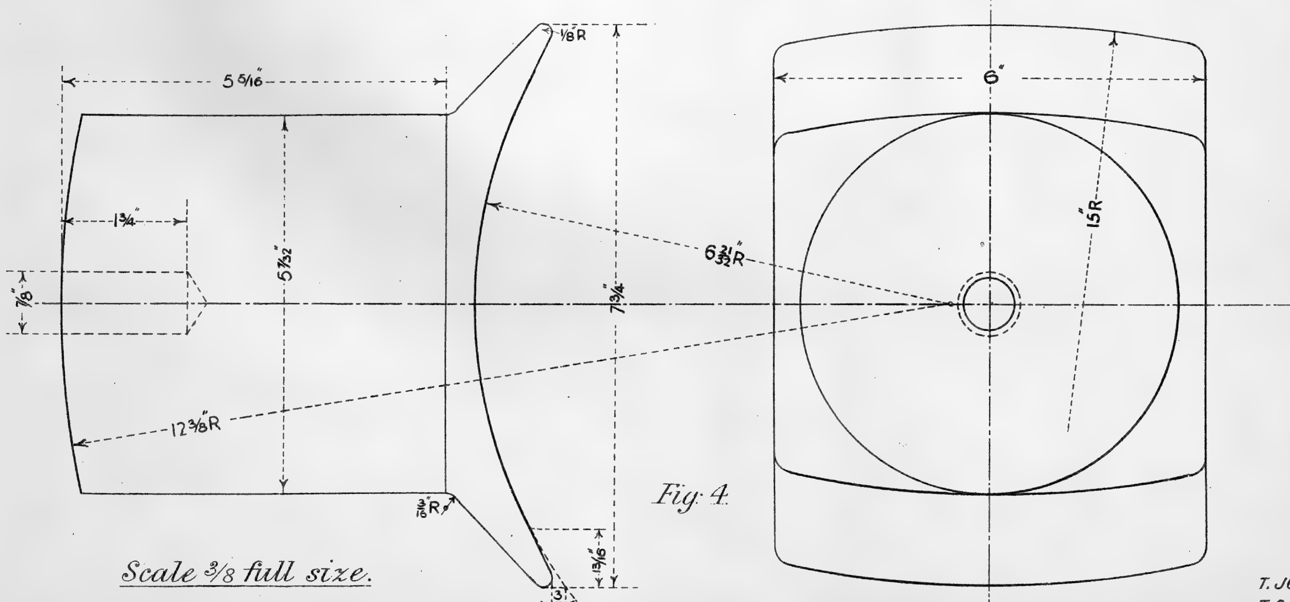

Fig. 4.

Scale 3/8 full size.

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Plate X.—FOUR-POLE ENCLOSED MOTOR.

GENERAL ARRANGEMENT.—The drawings on Plates X. to XV. inclusive represent fully a continuous current four-pole enclosed motor as made by the Edison and Swan United Electric Light Co. Ltd. The motor makes 1,000 revolutions per minute on a 225 volt circuit, and is capable of generating 8½ horse-power with a current of 32 amperes.

The motor body is of cast steel, and is provided with two cast-iron end-plates with which the bearings for the shaft are cast. On the inside are four laminated pole pieces—at 45° with the vertical—and for a length of 9 inches, in the centre of which the poles are fixed, the body is increased in thickness from ½ inch to 1 inch to form the magnet yoke. For purposes of ventilation there are three rectangular openings in the motor body opposite the commutator, and the upper portions of the end-plates are formed with radial arms. A motor of this design, where the commutator, armature, and field windings are provided with mechanical protection and are efficiently ventilated, is said to be of the "protected ventilated" type.

The armature is 10 inches diameter, 6 inches long, and is of the slotted drum-wound type with wave or series winding. It is provided with 40 slots, ·35 inches wide × 1 inch deep, and the winding consists of sets of three coils of two turns, each turn having 2 No. 15 S.W.G. wires in parallel, making 24 wires per slot. The armature core plates are keyed to the shaft, and clamped between the flanged end-plate and the commutator sleeve which are also keyed to the shaft and held endways by malleable iron nuts screwed on the shaft.

The commutator is 9 inches diameter, and has 119 copper bars which are rigidly clamped together. Three ventilating ducts pass through the armature and the commutator sleeve.

The shaft bearings are of the self-aligning type with gun metal swivel brushes, and the continuous lubrication is effected by means of oiling rings.

To the end-plate near the commutator the four sets of carbon brushes are fixed, and the cables for connection with the positive and negative terminals, and also for the magnet windings, pass through holes fitted with ebonite brushes in the same plate. The magnet winding may be either shunt or compound as required.

At one end the shaft projects beyond the bearing and carries a belt pulley for the transmission of the power generated by the motor to the driven shaft.

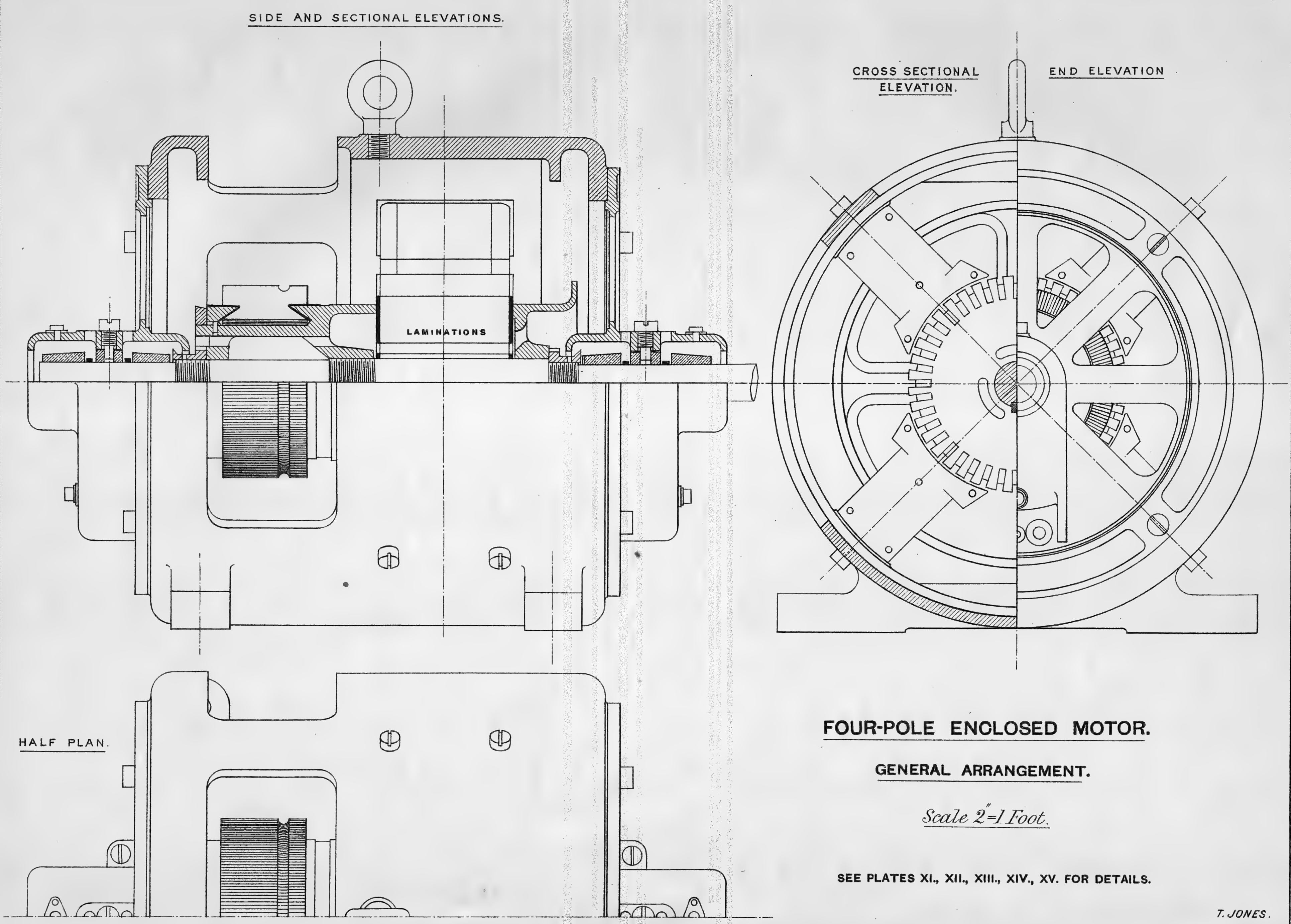
EXERCISE.

Complete Motor.—Draw the three given views.

If the drawing be made on a sheet of imperial size complete the plan. *Scale ⅜ full size.*

For half imperial, use *Scale 4″ = 1 foot.*

N.B.—On no account should the above exercise be attempted until all, or at least the more difficult, details have been drawn separately.



FOUR-POLE ENCLOSED MOTOR.

GENERAL ARRANGEMENT.

Scale 2" = 1 Foot.

SEE PLATES XI., XII., XIII., XIV., XV. FOR DETAILS.

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Plate XI.—FOUR-POLE ENCLOSED MOTOR.

MOTOR BODY.—The body is a simple casting of steel, $\frac{1}{2}$ inch thick, provided with two pairs of feet so that it may be held down by four $\frac{7}{8}$ inch bolts. On each side of the plane of the poles for a distance of $4\frac{1}{2}$ inches the body is made 1 inch thick to form the magnet yoke along which pass the magnetic lines of force—as explained in the notes on the four-pole generator. Since in this case the yoke is of cast steel the area of its cross section may be much smaller in comparison with the cross section of the poles than if it were of cast iron, because of the greater magnetic flux per square inch which may be allowed.

At each end of the body is an internal flange to which a cast-iron end-plate is secured by four $\frac{5}{8}$ inch screws. At the commutator end the body has three rectangular openings, 6 inches wide, for the purpose of ventilation. As is usual an eye bolt is screwed into the top of the body to facilitate the lifting of the machine.

There are four laminated pole pieces, and these are bolted on the inside of the yoke by $\frac{1}{2}$ inch screws: they are placed at 45° with the vertical.

Laminated Pole Piece.—When the pole pieces of a machine are of solid cast steel there is sometimes a slight loss of efficiency due to the unequal magnetic strength of the poles; so to avoid this and to check eddy currents in the pole faces laminated pole pieces are adopted by some makers.

In this example there are soft iron laminations—of the shape shown in the drawing—occupying a thickness of $4\frac{1}{2}$ inches which are clamped together by two side plates of wrought iron, $\frac{3}{4}$ inch thick. Five $\frac{1}{4}$ inch iron rivets with counter-sunk heads pass through the side plates and the laminations. The bobbins for the magnet windings will be of rectangular section.

The pole face subtends an angle of 60° at the centre, therefore the pole span will be $\left[\frac{60^\circ}{90^\circ} = \right]$ $\frac{2}{3}$ the pitch of the poles.

EXERCISES.

1.—**Laminated Pole Piece**. Draw two elevations and a plan. *Scale $\frac{3}{4}$ full size.*

2.—**Motor Body and Pole Pieces**. Draw the two given views, but show the side elevation completely in section, and add a half sectional plan. *Scale $\frac{3}{8}$ full size.*

THE ELECTRIC MOTOR.

During the rotation of the armature of a dynamo with a closed external circuit the current generated passes through the armature conductors, and the absorption of mechanical work in the generation of the current is due to the rotation of the conductors conveying the current against the magnetic pull upon them.

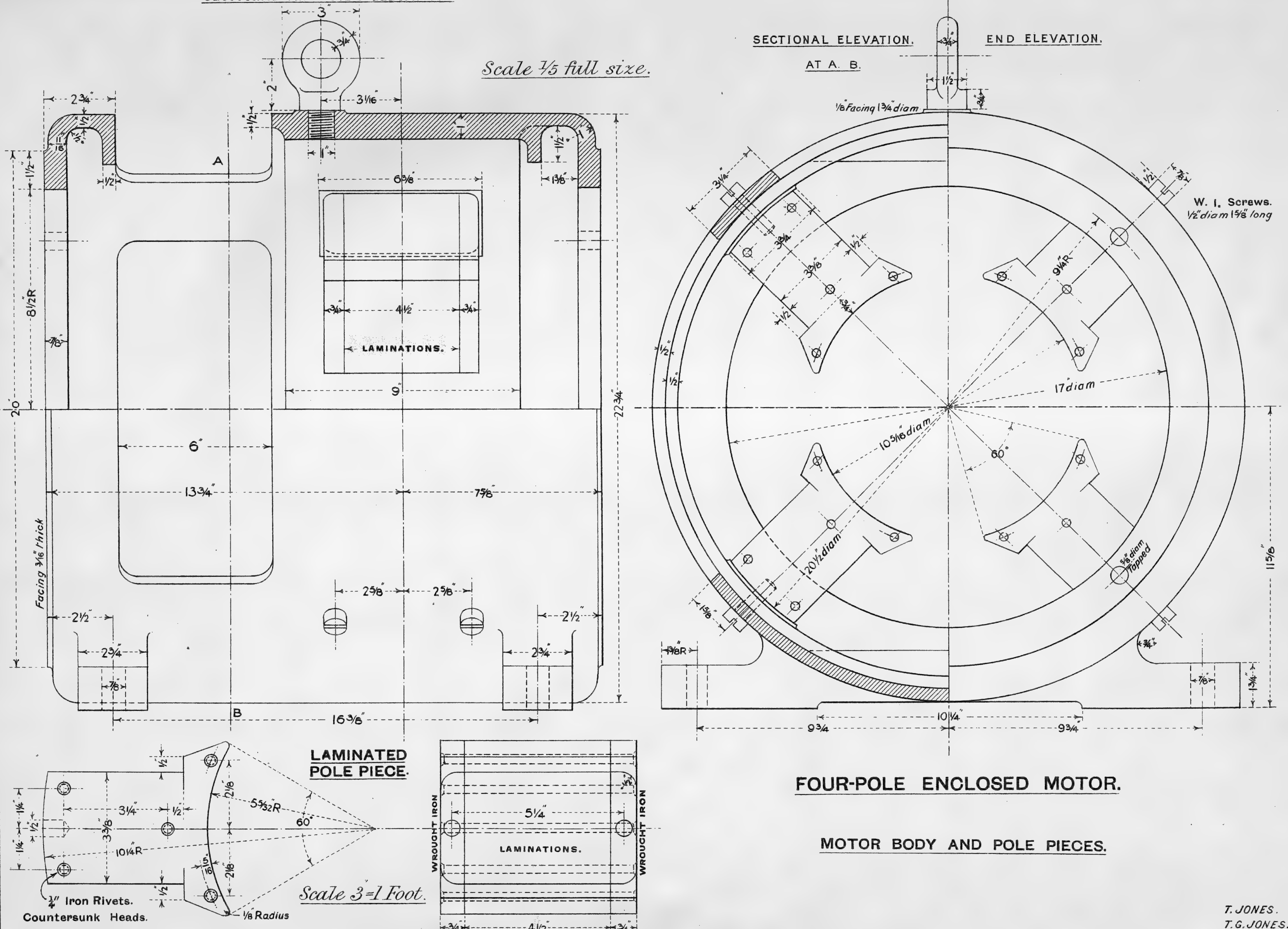
When, however, as in the case of the motor, a current is passed through the armature and the magnetic field is excited, the armature will rotate on account of the magnetic attraction between the poles and the armature wires, but the direction of rotation will be opposite to that in which the armature would rotate if generating a current which passed through the armature in the same direction.

On account of the action of the commutator the rotation of the armature will be permanent so long as the terminals of the machine are connected with the electrical supply; and the stronger the current passing through the armature the greater is the twisting moment which the shaft can exert. During the rotation of the armature of the motor in the magnetic field there is produced an electro-motive force (E.M.F.) which tends to send a current through the armature in a direction opposite to that of the current passing through it, and is therefore called a back E.M.F. The effect of the back E.M.F. is to diminish the E.M.F. urging the current through the armature, and therefore to diminish the strength of the current. The greater the speed of rotation the greater the back E.M.F., and the motor always tends to run at such a speed that the back E.M.F. becomes nearly equal to the terminal voltage.

When starting a motor there is no back E.M.F. to partially counteract the terminal voltage, and, since the armature resistance is comparatively small, there would pass through the armature an excessively large current—in fact so large as to destroy the insulation of the wires—unless means be taken to diminish the effective E.M.F. by a resistance in series with the armature resistance. This resistance is called the starting resistance.

The effect of variation of load on the speed of the motor depends upon the variation of the strength of the magnetic field and upon the magnet windings; hence it is evident that the various types of motors must for many questions be considered separately.

[*Continued on Plate XII.*



FOUR-POLE ENCLOSED MOTOR.

MOTOR BODY AND POLE PIECES.

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Plate XII.—FOUR-POLE ENCLOSED MOTOR.

END-PLATE AND BEARING.—The drawings show in detail the construction of the end-plate and bearing for the pulley end of the motor. The plate for the other end is the same design but has a few additional fittings—as shown on Plate XV.—because of the brush gear which is attached to it.

The plate and bearing are of cast iron and in one piece, and for purposes of ventilation the greater portion of the centre is divided up into arms. The arm section is shown in the side elevation. The plate is secured to the internal flange of the cast-steel body by four $\frac{5}{8}$ inch screws with cylindrical heads.

The cylindrical shell of the bearing which contains the bush projects outside the plate, and below it is the oil reservoir in the form of a large rectangular recess. The brass bush is 6 inches long and bored to a diameter of $1\frac{3}{4}$ inches, and in the centre of its length is supported so that it may have a slight swivel motion. The bush has two cast grooves on its upper surface so that by means of rings hanging on and revolving with the shaft the lubrication may be automatic. Such a system works perfectly well so long as the oil is not too thick and the rings dip well into it. The oil is supplied to the reservoir through the plug C, and occasionally withdrawn from it by means of the bottom plug D. The two oil holes are closed with small brass covers, and these are secured by means of a light chain to the brass piece at E.

EXERCISE.

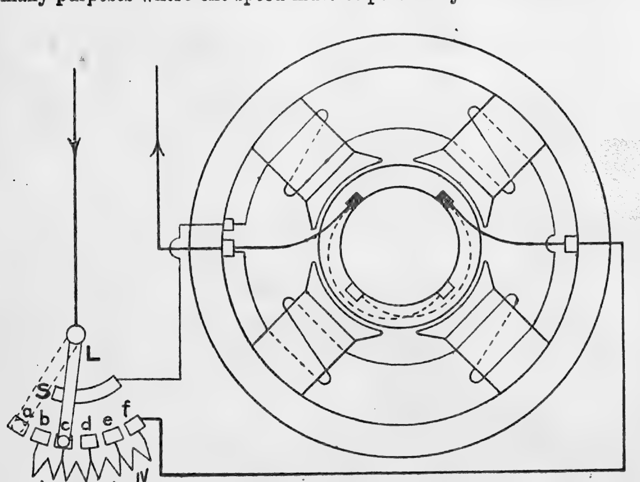
Bearing and End-plate.—Draw the side elevation and section as given, the complete sectional elevation, the complete plan projected from the side elevation, and an additional elevation to the left of the side elevation.

Show all the small details in position. *Scale $\frac{1}{2}$ full size.*

THE ELECTRIC MOTOR—*Continued.*

The Shunt Wound Motor.—From a previous description in connection with the dynamo it will be understood that, in this case, the magnet windings are coils with many turns of fine wire, and the magnet current is a shunt off the main circuit. The supply current is divided into two parts; one branch passes through the armature and the other through the magnet coils, but for the reason stated above only the shunt current has the full voltage on starting. With this type of motor, therefore, the strength of the magnetic field is practically constant for all loads; and the armature current, after the starting resistance is switched off, diminishes as the speed increases.

With an increase of load the speed falls slightly, and the back E.M.F. is reduced, therefore the current through the armature increases, and so the armature is capable of exerting a greater twisting moment. The larger the motor the smaller is the variation of speed; and, for many purposes where the speed must be practically constant under a varying load, the shunt motor is an excellent driving power.



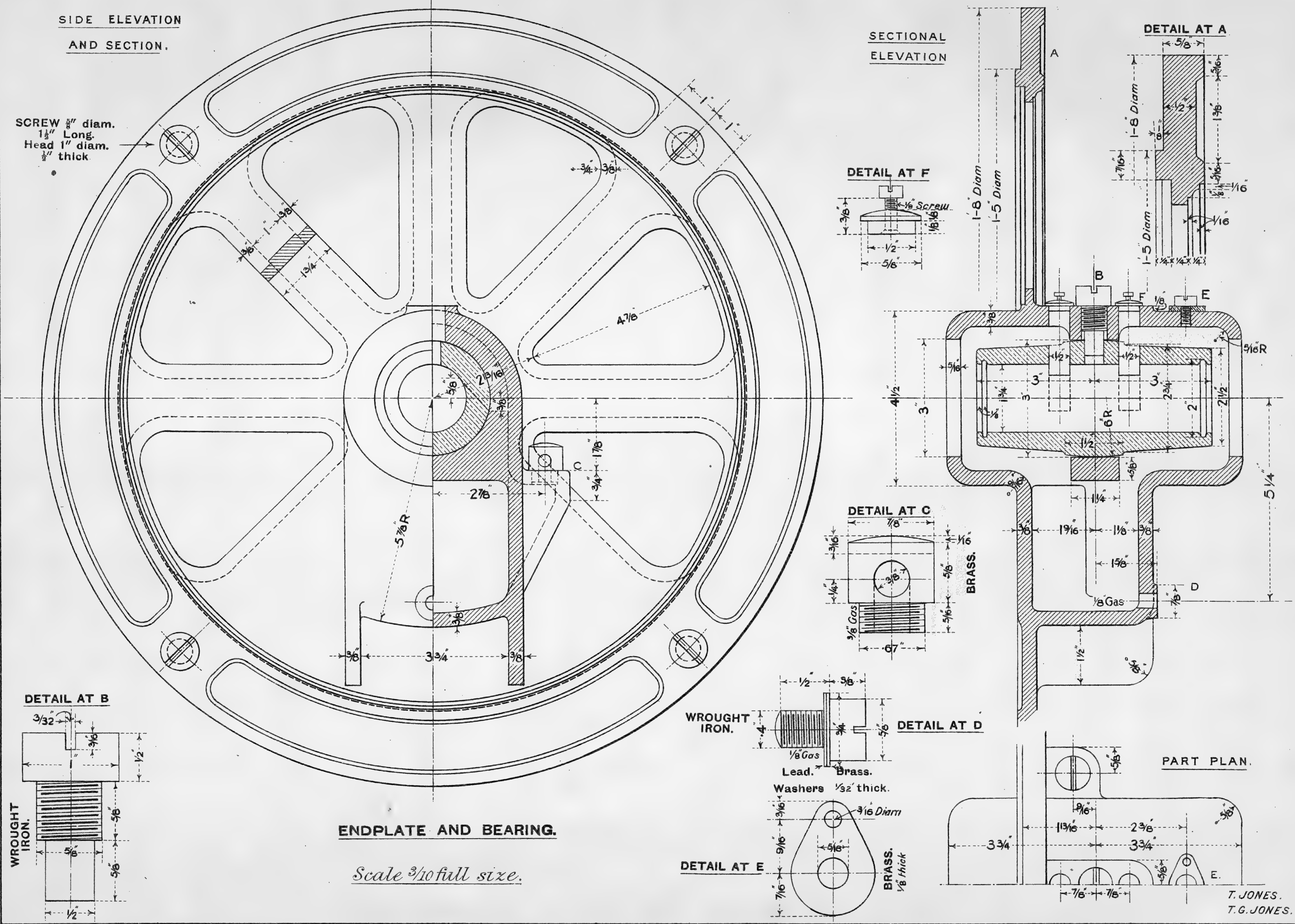
The accompanying figure shows diagrammatically the winding of the shunt machine and its connection with the starting switch. The centre of the starting lever L is connected with one main, and the lever slides over a number of contact pieces, *a*, *b*, *c*, *d*, *e*, *f*, and a slip ring S. All but the first contact piece *a* are connected with the ends of the resistance coils I., II., III., IV. The last contact *f* is connected with one brush terminal of the machine, and the slip ring with the shunt windings. The other end of the windings and the other brush terminal are connected with the second main.

When the lever is on contact *a* the motor is at rest since the lever is not connected with the slip ring or the resistance coils. If the lever be moved to the next contact *b* the slip ring becomes connected with one main, and so the magnet coils receive the full strength of shunt current. The armature current has to pass through all the resistance coils I., II., III., IV., and consequently the voltage at the brushes will be considerably less than that of the mains. As the speed of the motor increases the armature current decreases because of the increasing back E.M.F., and therefore the terminal voltage of the machine is increased by moving the lever over the contact *c*, *d*, *e*, and cutting out one by one the resistance coils. When the lever is on the contact *f* there is the full voltage at the brush terminals.

Shunt motor starters should be fitted with a "no voltage" release, so that if the supply current fail the levers will return to the "off" position. Without this device it would be necessary to switch off by hand all the motors before connecting up the current again, otherwise the full current would pass through the stationary armatures. An overload release is also desirable in many cases.

[*Continued on Plate XIII.*

FOUR-POLE ENCLOSED MOTOR.



ENDPLATE AND BEARING.

Scale 3/10 full size.

Plate XIII.—FOUR-POLE ENCLOSED MOTOR.

ARMATURE.—The armature is 10 inches diameter with a laminated core 6 inches long, and is of the slotted drum-wound type with wave or series winding.

The punchings are 10 inches diameter with 40 slots, ·35 inch wide × 1 inch long, and there are three segmental holes passing through them for the purpose of ventilation. Fitted in the shaft is a $\frac{1}{2}$ inch square feather key, and the laminations are threaded on the shaft and driven by this key. At each end of the core is a wrought-iron plate, $\frac{3}{16}$ inch thick, and these are pressed tightly against the core by the end plate on one side and the commutator sleeve on the other.

The end plate is of cast iron, and is flanged on the outside so that the armature windings may be securely packed. It has three ventilating holes opposite those in the core, and fits over the feather key which drives the core. The malleable iron circular nut which presses on the back of the plate also serves as an oil thrower.

The winding is made up of sets of three coils of two turns, each turn having 2 No. 15 S.W.G. wires in parallel, making 24 wires per slot. The arrangement is similar to that of the generator previously described, but in this case a set of coils would lie in slots 1 and 10. After reference to the armature winding for the generator it will not be difficult to draw the corresponding figure for the motor.

Commutator.—The construction of the commutator is clearly shown in the drawing. There is a long cast-iron sleeve cored out and provided with three ventilating holes so that there may be a clear air passage right through the armature and the commutator. The armature end of the sleeve screws on the shaft and is driven by the armature key; and the circular nut and oil thrower serves to lock the sleeve against the armature core.

The 119 bars are insulated from one another by mica sheets ·03 inch thick, and from the sleeve and commutator ring by the mica rings and tubes of pressboard. The clamping ring is pressed inwards by the circular nut which screws on the outer end of the sleeve, and is prevented from turning by the $\frac{1}{4}$ inch screw fitting in the short key way. The nut has two slots diametrically opposite for the purpose of turning it.

The $\frac{1}{2}$ inch semi-circular groove in the commutator bars separates the portion to which the armature wires are connected from that against which the carbon brushes rub. For the smooth and sparkless running of the brushes over the commutator it is necessary that the latter be kept smooth and true. Under ordinary circumstances an occasional use of glass cloth on the bars, while the machine is running, to remove any slight irregularities, followed by a cleaning with a slightly greased rag, will be all that is required.

EXERCISES.

1.—**Commutator.** Draw the given sectional elevation, a complete end elevation and a half plan. *Scale full size.*

2.—**Armature End-plate.** Draw the given sectional elevation, two half end elevations, one on each side of the section, and a half plan. *Scale full size.*

Do not show the armature punchings.

3.—**Complete Armature and Commutator.** Draw the longitudinal sectional elevation, two half end elevations and a plan. *Scale $\frac{2}{3}$ full size.*

N.B.—Care must be exercised in fixing the positions of the various views.

THE ELECTRIC MOTOR—*Continued.*

Speed Regulation of the Shunt Motor.—If a resistance be placed in series with the magnet coils, the shunt current and consequently the magnetic field will be weakened, and the speed will be increased by a definite amount depending upon the reduction of the shunt current. In this way the speed of the motor may be increased about 20 per cent. above the normal speed.

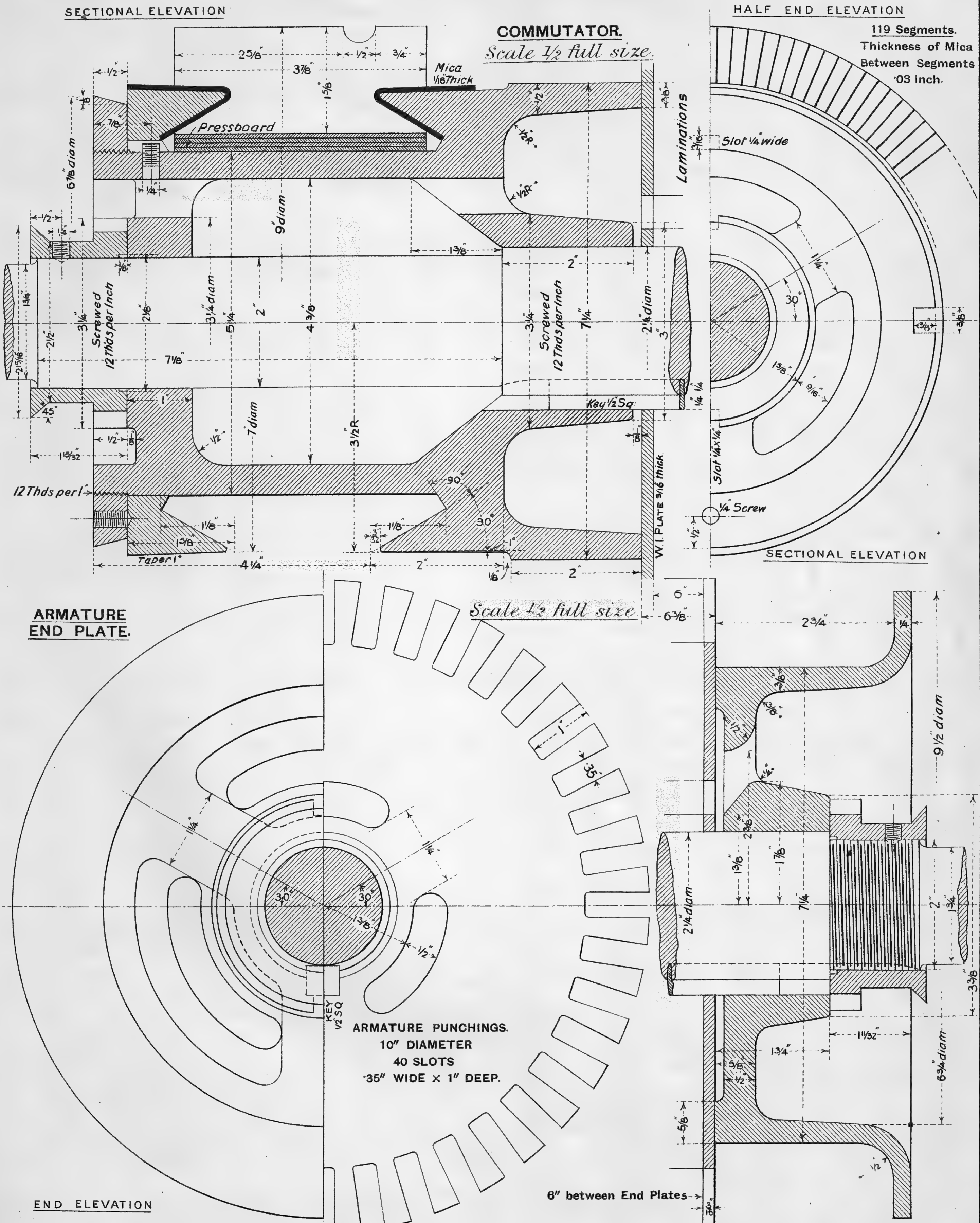
A reduction in speed may be effected by increasing the shunt current. If an external resistance be in series with the magnet coils during normal working, then when it is reduced or cut out the current will be increased and would produce a stronger field, and so bring about a slight reduction in speed.

Again, if the terminal voltage be reduced by switching in a series resistance the motor will run at a lower speed.

[*Continued on Plate XIV.*

FOUR-POLE ENCLOSED MOTOR.

DETAILS OF ARMATURE AND COMMUTATOR.



See Plate XV. for details of Armature Shaft.

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Plate XIV.—FOUR-POLE ENCLOSED MOTOR.

BRUSH HOLDER.—The given views show in detail the construction of the brush holder, of which there are four on the motor. It consists of the terminal block, the brush holder and trigger and two carbon brushes. On reference to Plate XV. it will be seen that the holders are rigidly secured to the end-plate and are not capable of any angular adjustment.

A teak base is fixed to an arm of the end-plate by two $\frac{5}{16}$ inch screws, and the brass terminal block is secured to the base by two screws. In the two $\frac{1}{2}$ inch holes of the block are placed the brass plugs which are soldered to the ends of the cables, and these are gripped firmly by the $\frac{5}{16}$ inch bolt.

The brush holder is a neat casting of brass provided with a rectangular box end to contain the brushes, and an arm at the end of which the triggers are pivoted. As shown on the drawing the brush holder is bolted to the terminal block so that its distance from the commutator is adjustable.

The two carbon brushes fit the box end of the holder and are pressed gently against the commutator by means of the brass trigger. Each brush is fitted with a copper end, and to this end is soldered a short length of tube for the purpose of securing the brush to the copper flexible. The brushes bear radially on the surface of the commutator, and with the gentle pressure exerted upon them by the spring loaded trigger they are able to follow any slight irregularities of the commutator without sparking.

This arrangement, where the holder is fixed and the brush slides in a box, is generally considered more efficient—particularly with high voltages—than the grip holder on a swinging arm; but, in order that the brushes may work freely, they may occasionally require lifting out and cleaning. If the trigger be lifted off the brush and moved back so that the direction of the coiled spring is on the other side of the centre about which the trigger moves, it will not tend to fly back, and the brush may be easily removed.

EXERCISES.

1.—**Teak Base and Terminal Block.** Draw the side and front elevations and the plan. *Scale full size.*

2.—**Brush Holder, Trigger and Brushes.** Draw the front elevation, two side elevations and the plan, showing one trigger removed. *Scale full size.*

3.—**Complete Brush Holder.** Draw the front elevation, the plan, and the end elevation to the left of the front elevation. *Scale full size.*

THE ELECTRIC MOTOR—*Continued.*

The Series Wound Motor.—This type of motor is used for traction purposes, for the driving of pumps through toothed gearing and for fans, and in other cases where constant speed is not essential and there is no possibility of the motor starting with no load.

The magnet coils are in series with the armature, and therefore the field is stronger the stronger the current through the armature. When running with a light load the armature and the field current would be very weak, and hence to produce a sufficiently high back E.M.F. the speed would be very high. For a heavy load the field would be stronger and the speed low, so that, without any regulation, the motor will adapt itself to the load.

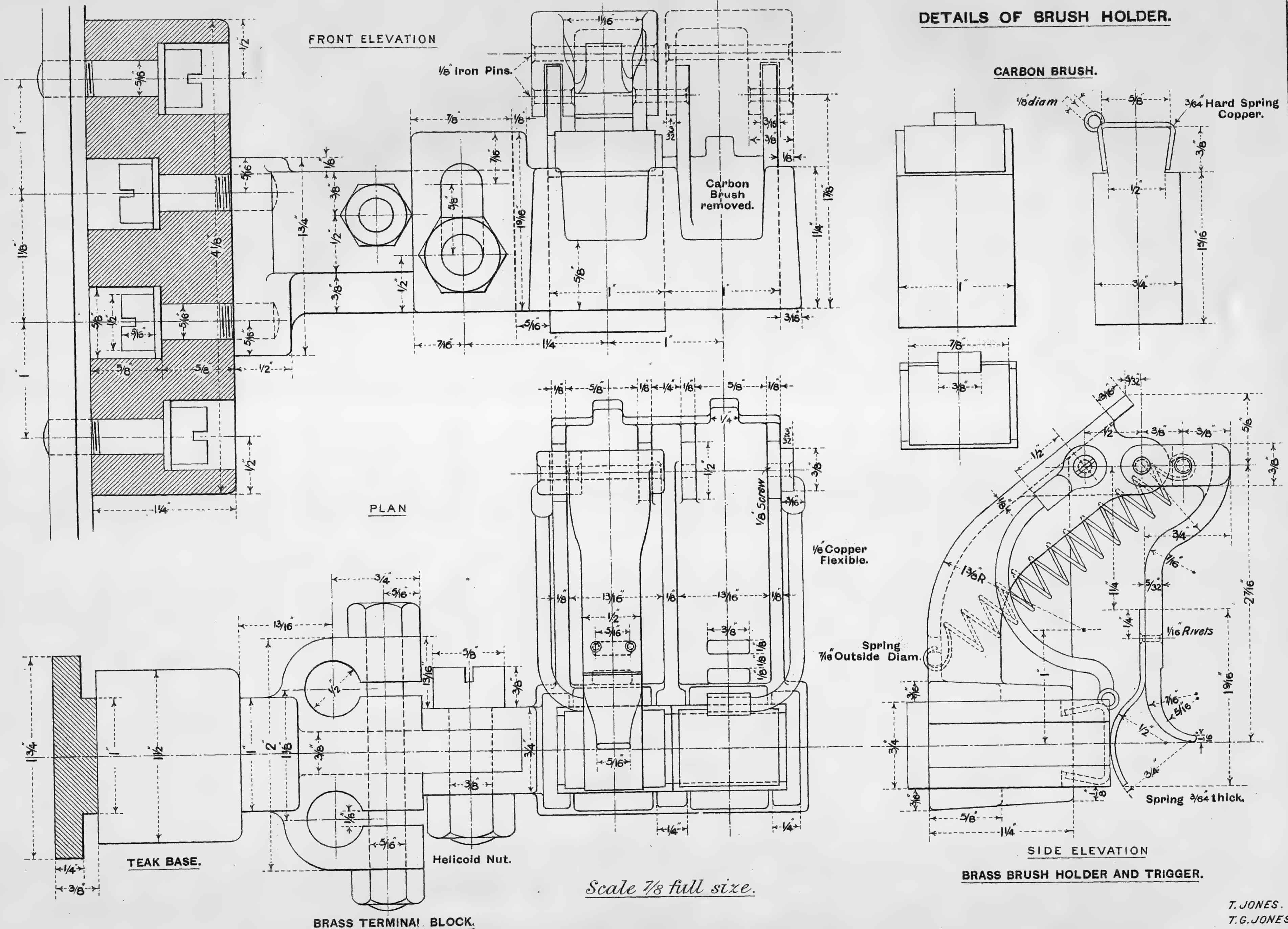
The twisting moment does not vary only with the strength of the armature current as in the shunt motor, but the simultaneous strengthening of the armature current and the field increases the twisting moment at a quicker rate than the current increases, and so the speed must fall with an increase of current. A series motor has a greater starting power than a shunt motor.

A series motor should never be used for a belt drive or where there is any possibility of the load failing suddenly, for then the speed would become dangerously high.

The starting switch is of simple construction, being merely provided with a starting resistance in series with the armature and magnet winding. For small motors it is quite practicable to dispense with the starting resistance and use a simple switch.

[*Continued on Plate XV.*

FOUR-POLE ENCLOSED MOTOR.



Scale 7/8 full size.

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Plate XV.—FOUR-POLE ENCLOSED MOTOR.

BRUSH GEAR.—The given elevation shows the arrangement of the brushes and connections for the motor.

Four brush holders with the teak bases are secured to the inside of the commutator end-plate at 45° with the vertical so that the brushes have no lead, and the motor may be run equally well in either direction. Except in one case only the terminal blocks are shown on the drawing so that the cable connections may be made clear. Diametrically opposite brushes are of the same polarity, hence it is necessary to connect them electrically. The two lower brushes form the terminals of the motor, and it is to the terminal blocks of these that the main cables are attached. The two smaller cables, used for connecting the opposite brushes, pass along the outside edge of the end-plate to which they are held by brass clips. The ends of the cables which are attached to the terminal blocks are soldered into brass plugs and clamped in the $\frac{1}{2}$ inch diam. holes. The two main cables X, which convey the current to the motor terminals, pass to the inside of the machine through ebonite bushes A screwed in the end-plate.

The size of the X cables is 19/17 S.W.G., which means that the conductor is made up of 19 wires of size 17 S.W.G. (·056 inch diam.) laid together spirally but without twist, every wire being tinned. The strand so formed is ·28 inch diam., and when covered with vulcanised indiarubber, taped and braided, has an external diameter of ·52 inch. Each cable Y, which conveys only half the total current, is 19/19 S.W.G., that is, the conductor is a strand of 19 wires of size 19 S.W.G. (·04 inch diam.)

The teak base screwed on the inside of the plate below the bearing is for the purpose of making the necessary connections for the magnet shunt winding. The two shunt wires pass through the small ebonite bush B, and each is connected to a brass screw on the base. To these same screws are connected the ends of the magnet coils.

To reverse the direction of running of the motor it is necessary to change the direction of the current through the armature or reverse the polarity of the field.

Motor Shaft.—The steel shaft has a total length of 3 feet $2\frac{19}{32}$ inches, and varies in diameter from $1\frac{3}{4}$ inches at the bearing to $2\frac{1}{4}$ inches where the armature is fixed. The shaft is screwed with 12 threads per inch in three places to receive one end of the commutator sleeve and the two oil throwers.

Fitted in the shaft, and held by a $\frac{1}{4}$ inch screw, is the $\frac{1}{2}$ inch square feather key which drives the several parts of the armature and commutator.

EXERCISES.

1.—**Shaft** Draw the given view. *Scale $\frac{1}{2}$ full size.*

2.—**Teak Base.** Draw the two given views. *Scale full size.*

3.—**Brush Gear.** Draw the given view, and add a sectional side elevation of the end-plate and a portion of the motor body, showing the bearing, the commutator in outside elevation, and the brushes in position on the commutator. In the latter view show two brushes turned into the vertical. *Scale $\frac{1}{2}$ full size.*

THE ELECTRIC MOTOR—*Continued.*

The Compound Wound Motor.—The winding of the field magnets is indicated in Fig. 2 of the notes on the dynamo; and the starting switch will be connected up as for the shunt machine, but the cable from the contact *f* must be in series with the series coils, and the other end of the coils connected with the brush.

If the series and shunt coils be wound round the poles in the same direction, the series coils strengthen the effect of the shunt coils, and so the motor has a greater starting power for a given strength of current than has a shunt motor. The more the series winding the easier it is to start the machine and the greater the variation of speed between no load and full load.

There is no danger if the load be suddenly removed, for with a very feeble armature current the series coils are ineffective and the motor runs as a shunt machine.

FOUR-POLE ENCLOSED MOTOR.

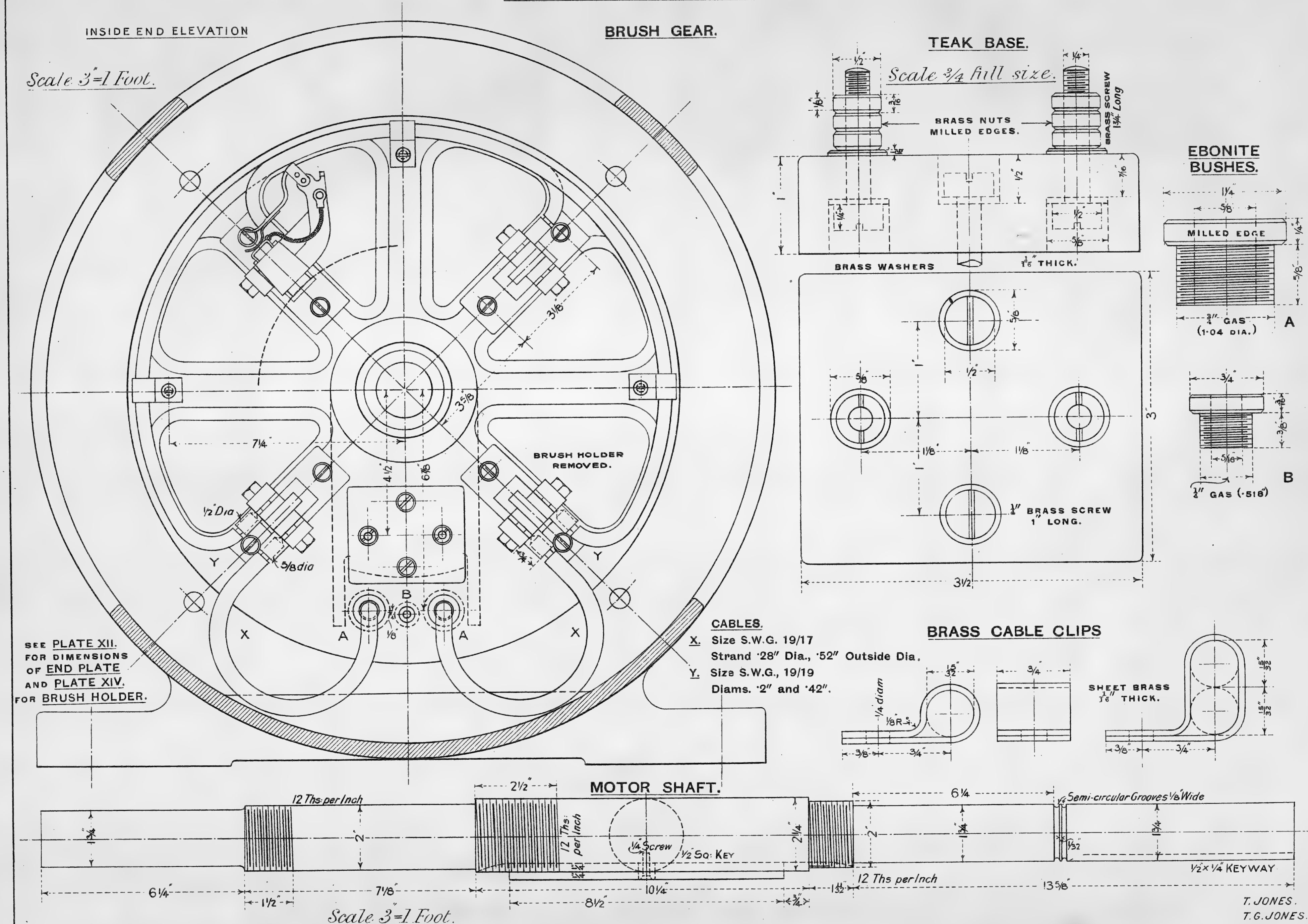


Plate XVI.—FIELD MAGNETS FOR SIX-POLE DYNAMO.

THE drawings represent the magnet yoke and pole pieces of a 165 kilowatt dynamo, which makes 390 revolutions per minute and generates current at 250 volts.

The yoke is of cast iron and made in halves, and the lower portion is provided with feet for connection with a bed-plate or directly with the foundation. The holes in the feet are not plain holes, but are tapped for a special holding-down device. The two halves of the yoke are bolted together by four 1 inch bolts, and to facilitate lifting the upper half has a tapped hole $2\frac{1}{4}$ inches diameter to receive an eye bolt. The yoke is of substantial section, and to the six curved facings on the inside are bolted the cast-steel pole pieces, each by two $1\frac{1}{8}$ inch bolts.

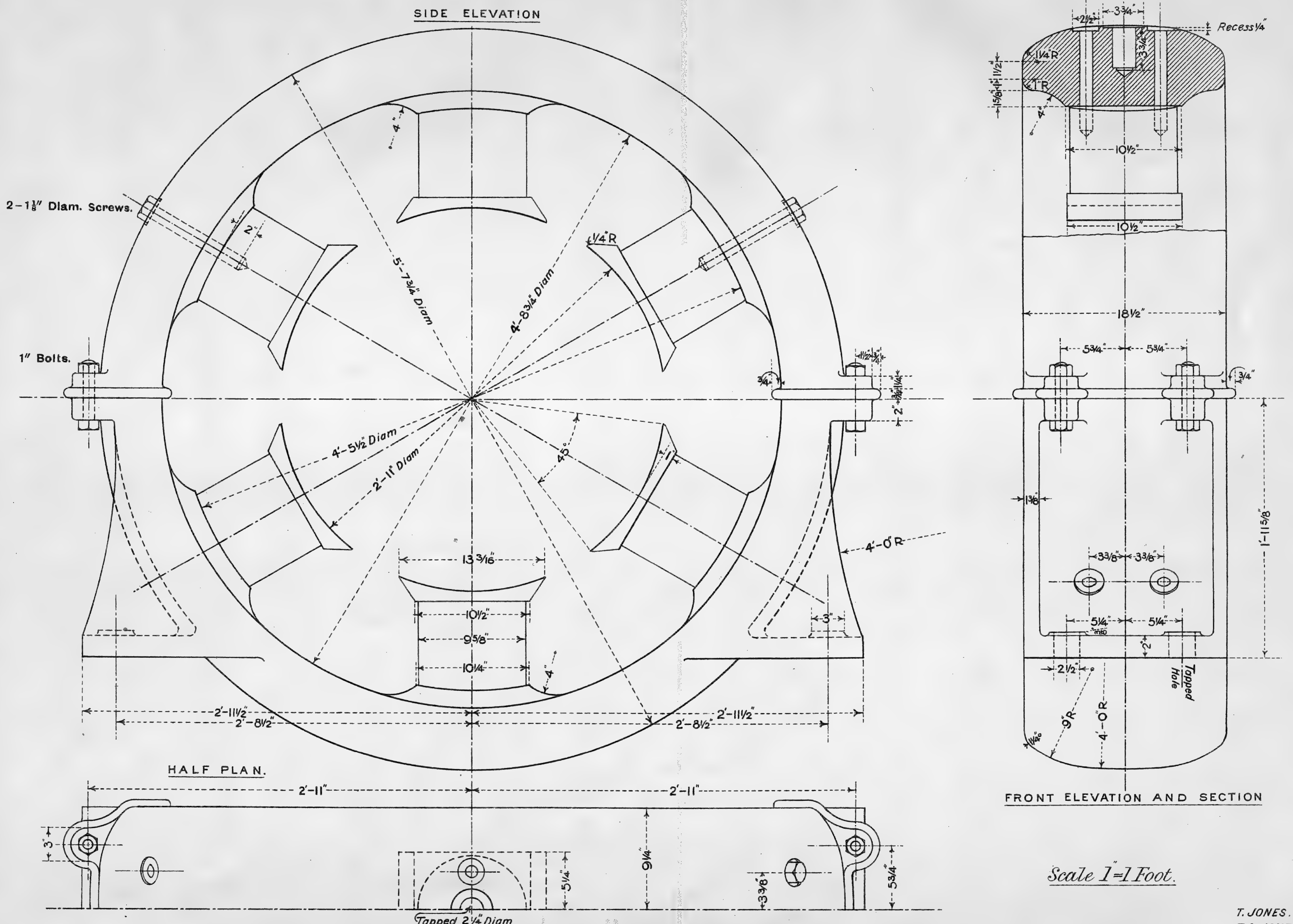
The pole faces are bored to a diameter of 35 inches, and the armature for this machine is 34 inches diameter with a core 12 inches long, therefore there will be an air gap of $\frac{1}{2}$ inch.

A pole face subtends an angle of 45° at the centre, and, since the poles are 60° apart, the length of polar arc is $\left[\frac{45}{60} = \right]$ ·75 of the pitch of the poles.

EXERCISE.

Magnet Frame and Pole Pieces.—Draw the side elevation, the front elevation and section and the complete plan. *Scale $\frac{1}{6}$ full size.*

FIELD MAGNETS FOR SIX-POLE DYNAMO.



Scale 1" = 1 Foot.

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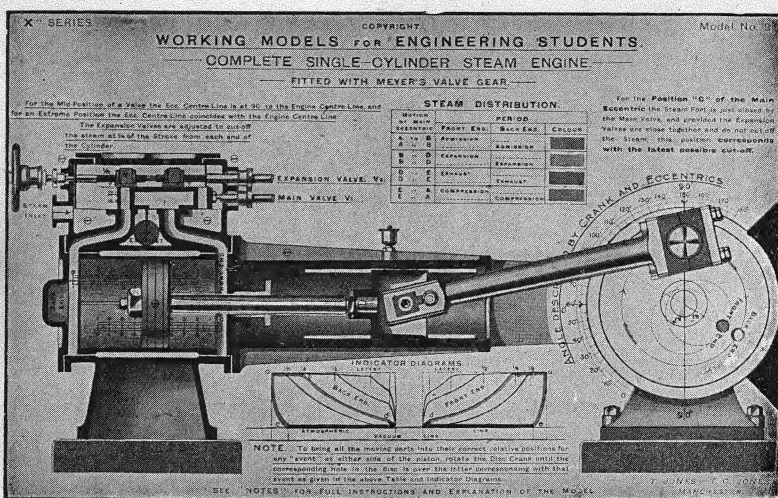

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